UNIVERSITY OF LEEDS

Leeds University Business School

Collective Idea Generation on an Online Platform: An Analysis of User Interactions on a Clickworkers' Platform

Liang Liang

Submitted in accordance with the requirements for the degree of Doctor of Philosophy

The University of Leeds

Leeds University Business School

December 2020

The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

Acknowledgements

This research has been supervised by an excellent academic team and received unreserved supports and helps from our industrial partner. Thanks for your irreplaceable contributions in the literature review, research design, getting access to the data, data analysis, and writing up. I would like to express my sincere gratitude to my supervisors, who provided guidance and feedback throughout this project. There were numerous times of encouragement and supports from you.

Content

Abstract

This study investigates how successful ideas are developed by clickworkers, i.e. freelancers who utilise workplace online platforms to create, modify and evaluate ideas. The existing literature suggests that idea generation outcomes are not only a product of individual level factors (such as participants' experience, intelligence and accessibility to idea-related information), but are also a product of collective ideation activities that take place among participants. However, it has been noted that collective ideation activities among participants through modern IT remains under-studied. In particular, we know little about IT-enabled ideation and innovation performed by increasingly popular labour markets (Boudreau and Lakhani, 2009) by clickworkers. This research aims to address these gaps by investigating influence of collective ideation activities such as collective idea creation, voting and ranking of ideas on ideation outcomes.

The research context of this dissertation is Codigital, an ideation platform that enables collective creation, editing, voting and ranking of ideas. Based on the results of social network analysis and regression modelling, the findings provide insight into which participant ideation behaviours are beneficial and which are not, by suggesting that: (a) participant isolation, which means participants engage in ideation activities individually rather than collectively with other participants, has a negative influence on idea quality; (b) participants inactivity, which means participants rarely engage in ideation activities, has positive influences on idea quality; and (c) centralities, which represent the connectivity among collective ideation activities, have positive influences on idea quality.

1. Introduction

Clickworkers, defined as people who carry out routine required tasks for an online project (Kanefsky et al., 2001), are considered a category of the labour market and also a form of crowdsourcing (Boudreau and Lakhani, 2009). Idea generation (also referred to as 'ideation') is defined as exposure to and acquisition of relevant information (Björk and Magnusson, 2009) that provides possible solutions to a problem (Girotra et al., 2010). There are benefits of using clickworkers for this purpose; however, it remains unclear how exactly clickworkers contribute idea quality and ideation processes during idea creation and evolution (Morschheuser et al., 2017). Thus, this research investigates how successful ideas are generated by clickworkers through collective ideation activities on an online platform.

The following three research gaps motivate and set the boundary for this study. First, previous studies on ideation have emphasised the importance of individual idea contributors in generating successful ideas, while downplaying the role of idea co-creation as a collective process (Shalley, Zhou, and Oldham 2004; Zhou and Shalley, 2010). Second, where the collective interaction-based approaches to idea generation have been considered (Tsoukas, 2009; Anderson et al., 2014), they have mainly privileged the study of how ideas are proposed by multiple participants, thus neglecting the evolution of ideas based on collective processes such as idea editing, combining and voting for better ideas (Harvey and Kou, 2013; Perry-Smith and Mannucci, 2017). Third, while previous studies have increasingly acknowledged the important capabilities of information technology (IT), such as online platforms, in improving idea quality during the idea generation process (Majchrzak and Malhotra, 2013; Nakatsu et al., 2014; Nambisan and Baron, 2010; Perry-Smith and Mannucci, 2017), there is a lack of detailed knowledge about what factors affect the successful collective generation of ideas on online platforms.

Furthermore, contemporary IT has been widely applied to facilitate idea generation in business innovation (Perry-Smith and Mannucci, 2017). IT enables organisations to involve a variety of actors from both within and beyond organisational boundaries (Chesbrough 2003; McMillan and Overall, 2016). Thus, online idea generation provides an online environment for creating, developing, voting on and moderating ideas, rather than simply connecting participants to collaborate on idea generation (Majchrzak and Malhotra, 2013; Nakatsu et al., 2014). Additionally, idea generation on online platforms also helps to increase the number and diversity of generated ideas, since it potentially increases knowledge recombination through bridging different individuals and sub-groups (Nambisan and Baron, 2010), and also manipulates the identities of contributions to overcome potential biases (Gibson and Gibbs, 2006; Huizingh, 2011; West and O'Mahony, 2008; Van De Vrande, Vanhaverbeke and Gassmann, 2010). However, despite increasing interest in this area, our knowledge of what factors affect the successful collective generation of ideas on online ideation platforms remains limited.

This research aims to address the above gaps by exploring collective ideation activities among clickworkers (i.e. participants in idea generation projects) using a platform called Codigital (www.codigital.com). Codigital is a cutting-edge IT ideation platform that enables large groups of participants to generate, prioritise and refine ideas. As an online idea generation platform, the Codigital ideation tool consists of user interface, data process and storage system, and an artificial intelligence program. In idea generation projects, ideas are proposed online by individual participants. They then collaborate and compete to combine ideas together into better ideas. The Codigital ideation tool consists of five parts, 'add ideas', 'edit ideas', 'vote edits', 'vote ideas', and 'rank ideas'. These five parts are consistent with

previous theories suggested that ideation process is creation, modification, voting, and selection (Lindic, et al., 2011; Majchrzak and Malhotra, 2013; Nakatsu et al., 2014). Idea creation is represented by 'add ideas' in the Codigital ideation tool. Idea modification consists of 'edit ideas' and 'vote edits'. Idea voting is 'vote ideas' and idea selection is through 'rank ideas'. Users vote on pairs of ideas. This process is repeated, and statistical analysis of all these idea pair competitions identifies the best ideas. In this way, Codigital provides an opportunity to explore the influencing factors of collective ideation activities among participants in the context of IT-enabled idea generation, which is important from both theoretical and practical perspectives.

In particular, this study argues that ideation with clickworkers represents a particularly open process and enables a high level of openness with regard to entrance requirements, participant inclusion, and idea selection, editing and voting. In this regard, ideation with clickworkers enables the capturing of collectively shaped insights and innovative developments on a broad range of questions (rather than requiring specific expertise) from a wide range of diverse actors whose participation in ideation is valuable beyond the idea generation phase (i.e. participants can modify, edit and evaluate ideas). As a representative of such broad questions and open participant contributions, this research analyses clickworkers' ideation at the following two projects: Project 1 'What should our global New Year resolutions be?' (with 83 participants) and Project 2 'What measures would you recommend to ensure the safety of young people on social media?' (with 325 participants).

This research applies network analysis to conceptualise participant collective interactive activities and behaviours as networks consisting of ideas (as nodes) and collective ideation activities including votes and edits (as ties connecting those nodes). In other words, this

research analyses each idea generation project as a network; the nodes are ideas and ties are collective ideation activities among them through the project by using the Codigital platform. Data about the collective ideation activities among idea generation participants are recorded by the Codigital ideation platform. The data provides the basis for the network structure analysis and regression modelling to reveal collective ideation activities in idea generation.

The results of this study provide valuable information about clickworkers in online ideation and, in particular, about their behaviours when engaged in ideation. This study fills the three research gaps mentioned above. The results of this study show the influences of (a) participants' isolation; (b) participants' inactivity; and (c) centralities in idea quality. First, findings related to participants' isolation show that participants engage in ideation activity individually rather than collectively with other participants, which can significantly reduce idea quality. Second, findings related to participants' inactivity show that participants who engage less frequently in ideation activities contribute more to idea quality. Third, findings related to centralities show that ideas connected by collective ideation activities are of better quality. The results of this study can increase understanding of collective IT-mediated ideation as well as of factors influencing the quality of collective idea generation. In particular, the findings increase our understanding of which kinds of participants and which kinds of collective ideation activities can influence online ideation outcomes. These include the negative influence of participants' isolation on idea quality; the positive influence of participants' inactivity on idea quality; and the positive influence of centrality on idea quality.

This study opens with a literature review, which presents the relevant theories in the area of online ideation and the use of online platform and clickworkers (Section 2). Then, the theoretical framework and research questions are established (Section 2). In order to answer

the proposed research questions, network analysis is discussed in the methodology section (Section 3). The findings are presented and discussed in Sections 4 and 5. Finally, Section 6, 7 and 8 provide implications, limitations and future research directions, and a conclusion.

2. Literature review: idea generation and idea generation online platforms

2.1. Collective idea generation

As mentioned in the Introduction, idea generation is defined as exposure to and acquisition of relevant information (Björk and Magnusson, 2009). Exposure to information entails seeking and receiving information (George, 2007); this is also considered a person's accessibility to relevant information about ideas. The acquisition and recognition of information (Anderson et al., 2014) relies on a person's knowledge about the subject area and their familiarity with information related to the idea. Thus, ideas are generated in a process of seeking, receiving, recognising, and modifying information. Idea generation also implies the application of experiences, intelligence and accessibility to idea-related information (Hargadon, 2006). The possibility of individuals to generate ideas is a result of experiences, intelligence and accessibility to related information flows. To summarise, the results of individual idea generation can be influenced by two factors: (a) the individual's experiences, intelligence and accessibility to related information; and (b) the acts of seeking, receiving, recognising and modifying information. However, idea generation is more than an individual process. For example, ideas in the context of business innovation are not only about improving products and services, but are also about new business models, new market opportunities, new supply sources, new ways of production and new ways of organising tasks. These innovations stem from a set of potential sources both inside and outside the organisation, such as employees, partners, collaborators, independent inventors and customers (Cooper and Edgett, 2007).

In this research, idea generation is defined as a sequence of activities: seeking, receiving, recognising, and identifying information (George, 2007; Björk and Magnusson, 2009; Anderson et al., 2014), which can proceed not only at the individual and but also the collective level. Collective idea generation consists of co-creating ideas and then combining participants' ideas together into new ideas (Harvey and Kou, 2013). Studies in this area have focused on analysing the connections between participants' ideas (Perry-Smith and Mannucci, 2017) and the combination of participants' ideas into new ideas (Hargadon, 2006; Kimble et al., 2010). Previous research suggests that ideas are co-created collectively (Harvey and Kou, 2013) by exploring the new intersections between already existing knowledge areas (Hargadon, 2006). High-quality innovation ideas are usually generated collectively rather than individually (Perry-Smith and Mannucci, 2017). Connectivity among participants' ideas is positively associated with creativity in innovation (Björk and Magnusson, 2009). Thus, idea co-creation is considered to be a way to improve the quality of ideas. This is especially true today; given the development of information systems and online platforms, collective co-creation can take place in online environments.

Previous studies have provided explanations of how successful ideas are generated based on two key approaches, the componential theory of creativity and the interactionist theory of creativity. The componential theory of creativity has focused on explaining who contributes to idea generation results (Amabile, 1997; Amabile and Conti, 1999). This theory suggests that ideas are generated by people with expertise, creative-thinking skills and motivation. As a result, research in this area (Shalley et al., 2004; Zhou and Shalley, 2010) has explained that individual knowledge and psychological mechanisms are the most influential factors on the results of idea generation. However, such explanation emphasises they key role played by a

few individuals with experience, intelligence, accessibility to related information, and the ability to seek, receive, recognise and identify information. This suggests that none of these factors is easily manageable and easily improved in the short term during idea generation projects (Björk and Magnusson, 2009). In this regard, research has increasingly called for a need to find a new way of understanding and managing the idea generation process (Perry-Smith, 2006; Shalley, Zhou and Oldham 2004; Zhou and Shalley, 2010). Thus, idea co-creation has been suggested as a way to improve creativity in idea generation (Litchfield and Gilson, 2013). Since previous studies have acknowledged that collective co-creation of ideas is associated with higher value (Björk and Magnusson, 2009; Anderson et al., 2014; Perry-Smith and Mannucci, 2017), it is necessary to increase understanding of how ideas can be created collectively in a more efficient way. However, the componential theory of creativity has not yet provided many insights into what factors, beyond individual experiences, intelligence, accessibility to information and skills in managing it, make a collective idea co-creation successful.

In contrast, the interactionist theory of creativity highlights the fact that the results of idea generation depend not only on participants' experiences, intelligence, and accessibility to idea-related information (Lingo and O'Mahony, 2010; Afuah and Tucci, 2012), but are also co-shaped by the collective and interactive activities and behaviours among the participants (Tsoukas, 2009; Anderson et al., 2014). Thus, idea generation consists of a combination of individual activities, such as proposing ideas, and collective activities, such as editing, combining and voting for better ideas (Harvey and Kou, 2013; Perry-Smith and Mannucci, 2017). However, current research in idea generation online platforms has focused on how ideas are created rather than on how they evolve (Simula and Ahola, 2014; McHugh et al.,

2016; Schemmann, et al., 2016), thus neglecting an important aspect of idea generation, that it is co-shaped by the collective and interactive participants' activities.

To summarise, previous research has provided different explanatory approaches (e.g. componential and interactionist theories of creativity) to explain how successful ideas are generated and focused on explaining ideation at the organisational, team and individual levels (Anderson et al., 2014). While research has suggested that collective ideation activities, including voting and co-editing, are potentially important for ideation (Tsoukas, 2009; Suh et al., 2011; Perry-Smith and Mannucci, 2017), little is known about how these collective ideation activities influence the outcome of idea generation on IT-mediated platforms. To address these gaps, this research focuses on idea evolution and recombination enabled by modern IT, an area still under-theorised, and on how successful ideas are generated by individuals and then evolve through online collective activities on an online ideation platform.

2.2. Idea generation on online platforms

Contemporary IT has been widely applied to facilitate idea generation in business innovation (Perry-Smith and Mannucci, 2017). IT enables organisations to involve a variety of actors both from within and beyond organisational boundaries (Chesbrough 2003; McMillan and Overall, 2016). IT helps in many ways. Online idea generation provides an online environment for creating, developing, voting on and moderating ideas instead of simply connecting participants to collaborate in idea generation (Majchrzak and Malhotra, 2013; Nakatsu et al., 2014). Additionally, idea generation on online platforms also helps to increase the number and diversity of generated ideas, since it potentially increases knowledge recombination through bridging different individuals and sub-groups (Nambisan and Baron,

2010), and also manipulates the identities of contributions to potentially overcome various biases (Gibson and Gibbs, 2006; Huizingh, 2011; West and O'Mahony, 2008; Van De Vrande, Vanhaverbeke, & Gassmann, 2010). However, despite increasing interest in this area, our knowledge about what factors impact successful collective generation of ideas on online platforms remains limited.

Idea generation online platforms are software tools and/or infrastructures for sharing and generating ideas through the Internet (Dodgson, et al., 2006; Majchrzak and Malhotra, 2013). As a software tool and infrastructure system, an idea generation online platform usually consists of a user interface, a data and storage system, and in some cases, an artificial intelligence program (Lindic, et al., 2011; Maciuliene and Skarzauskiene, 2011). Idea generation online platforms are usually designed for idea crowdsourcing, which includes the ability to broadcast a call for relevant expertise and to search for ideas (Felin et al., 2017). Instead of simply connecting participants to collaborate in idea generation, idea generation online platforms provide an online environment designed for creating, developing, voting and moderating ideas (Majchrzak and Malhotra, 2013; Nakatsu et al., 2014). This is shown in Figure 1.

Figure 1

Collective ideation process

As Figure 1 illustrates, ideas on idea generation online platforms are created individually at first, and are presented and visualised using text and pictures (Dodgson et al., 2006). Then,

the ideas are modified and improved through collaboration among participants (Lindic et al., 2011). Each participant's idea competes with those of others through voting (Lindic et al., 2011; Majchrzak and Malhotra, 2013). Finally, ideas are moderated and ranked in order to be selected (Majchrzak and Malhotra, 2013). The effectiveness of an idea generation online platform is based on how well participants collaborate to refine ideas and on how well ideas compete with each other (West and O'Mahony, 2008). Thus, research is needed on how ideas evolve after they are created on idea generation online platforms.

To summarise, ideas are created individually and evolve collectively on idea generation online platforms. Ideas are created by individual participants and then evolve through re-combinations, editing, and voting (Maciuliene and Skarzauskiene, 2011). In this light, ideation simultaneously encourages collaboration and competition in refining ideas. Thus, idea generation online platforms need to be designed not only to facilitate competition in creating ideas individually but also to encourage collaboration in refining those ideas. While studies (Dodgson et al., 2006; West and O'Mahony, 2008; Lindic et al., 2011; Majchrzak and Malhotra, 2013) on idea generation online platforms provide details on how ideas are created and modified, little is known about how ideas evolve after they are created. Participant involvement in idea evolution (e.g. through voting and editing ideas of others) might impact the ideation process in general and the quality of created ideas in particular.

2.3. Towards an understanding of participant contributions on online idea generation platforms

This section discusses how participants can be involved and contribute to collective ideation on idea generation platforms. It also provides insights into how participants' online collective activities influence idea quality. This includes the characteristics of clickworkers (Section

2.3.1); participant involvement based on engagement into idea generation (Section 2.3.2); and participant involvement based on a person's embeddedness to the network (Section 2.3.3).

2.3.1. The role of clickworkers in online collective idea generation

This section compares clickworkers with other forms of crowdsourcing and then presents the research questions. Clickworkers, as previously defined, are individuals working on an online project and doing routine required tasks. In the context of online ideation, the term 'clickworkers' often refers to freelancers (Morschheuser et al., 2017). The original use of clickworkers, and the origin of the term, occurred in 2001, when a NASA experimental project used public volunteers, whom they nicknamed 'clickworkers'. Online ideation using clickworkers is defined as the acquisition of ideas from a group of Internet users (Battistella and Nonino, 2012; Brabham, 2013; Howe, 2006). The results of online ideation using clickworkers are cumulative, combining contributions from the participants.

Clickworkers are usually motivated by (a) financial incentives; (b) personal interest in the project; (c) a sense of personal achievement when leading the ideation project; and (d) a personal commitment to volunteer work (Howe, 2006; Brabham, 2013). However, Lévy (2010) suggests that the use of clickworkers is a transformation of the Internet into a worldwide knowledge management system. The use of clickworkers is known to increase the capacity of human collectives to engage in intellectual cooperation in order to create ideas (Neisser, 1979; Lévy and 2010; Goertzel, 2007). Peters and Heraud (2015) define collective intelligence in social innovation. From their perspective, the use of clickworkers is based on collective awareness and collective action. They also highlight the fact that the use of clickworkers is a form of co-creation and co-production of goods and services.

Crowdsourcing in idea generation is a process of broadcasting a call for ideas to individuals with relevant expertise and eliciting ideas (Afuah and Tucci, 2013; Felin et al., 2017). Crowdsourcing can be organised in three forms. First, instead of only involving a few experts, crowdsourcing can involve a large number of participants. Second, instead of only involving internal experts, crowdsourcing draws from relevant expertise outside the organisation in idea generation. Third, instead of only involving known external participants, crowdsourcing involves previously unknown external participants. Table 1 summarises specific characteristics of ideation with clickworkers; the rest of the section will specify and position clickworkers according to these three forms of crowdsourcing.

Table 1

Summary characteristics of ideation with clickworkers

Degree of openness and details	Clickworkers on ideation platforms
• High level of openness with regard to entrance requirements	• Entry criteria specified by those launching ideation • Typically low barriers of entrance for participation • Openness to various types of questions/ideation topics
• High level of openness in the process of idea selection, editing and voting	• Cumulative contributions (ability to modify, build on and vote for peers' ideas)
• High level of openness in the process of participant inclusion	• Participants as ideation networks without dependency of hierarchical position or external/internal membership • Inclusion of previously unknown participants

As Table 1 illustrates, ideation with clickworkers represents a particularly open process and enables a high level of openness with regard to entrance requirements, participant inclusion, and idea selection, editing and voting. In this regard, using clickworkers on ideation

platforms is particularly well suited for capturing collectively shaped insights and innovative developments on a broad range of questions (rather than requiring specific expertise) from a wide range of diverse actors whose participation in ideation is valuable beyond the idea generation phases (i.e. participants can modify, edit and evaluate each other's ideas). Below, I discuss details of the summary characteristics of ideation with clickworkers as shown in Table 1.

Crowdsourcing can involve a large number of participants; however, it still relies on individual contributions. The advantage of using clickworkers, from the perspective of the componential theory of creativity, is that it reduces dependency on individual contributions to generate ideas. Clickworkers generate ideas through cumulative contributions rather than individually, so idea quality does not rely entirely on individual contributions. Crowdsourcing can involve external experts; however, it still relies on individual expertise. The advantage of using clickworkers, from the perspective of the interactionist theory of creativity, is that it can overcome dependency on expertise in creating ideas, since ideas are refined and recombined through editing and voting collectively.

The benefits of using clickworkers are not limited to reduced ideation time, reduced ideation cost, competitive advantage and stakeholders' satisfaction (Bothos et al., 2009; Rouhani et al., 2016). Rouhani et al. (2016) used a quantitative survey-based study with a sample size of 228 firms to test the relations between the use of clickworkers and the benefits at the organisational level. The results provided meaningful insights for research and investment in the use of clickworkers. Also they enabled managers to better understand what they can achieve by using clickworkers for ideation. Bothos et al. (2009) explored the use by clickworkers of IDeM, a novel Internet-based software ideation tool that can be used for

generating and evaluating new ideas. They found the use of clickworkers to be particularly beneficial to the quality of ideas generated.

Crowdsourcing can locate previously unknown external participants in idea generation; however, it cannot enable their participation (Sharma et al., 2002; Piezunka and Dahlander, 2015; Schemmann et al., 2016). Crowdsourcing in idea generation consists of idea broadcasting (a call for ideas) and idea search (the next stage after idea broadcasting) (Afuah and Tucci, 2012; King and Lakhani, 2013). In idea research, the participation of previously unknown external participants can increase the diversity of participants and ideas. However, previously unknown external participants usually have to join an existing team to work together, and then their expertise is usually submerged by the existing experts. In contrast, using clickworkers is a way to bring previously unknown external participants' ideas forward, and these can be voted on without consideration of who created them. Figueroa and Pérez (2018) suggest that the use of clickworkers transforms ideation from administrative management to smart management by using people as ideation networks and their knowledge as an intangible asset. They also suggest that the use of clickworkers enables ideation systems to respond to changes in the business and market environment more efficiently. These benefits can be summarised as follows:

1. The use of clickworkers on ideation platforms is an easy and efficient way to generate and evaluate ideas compared to traditional methods (e.g. brainstorming).
2. Ideation platforms using clickworkers enable user involvements by creating new ideas, editing and commenting on each other's ideas, and idea rating.
3. Clickworkers can be used by commercial organisations for idea generation and evaluation.
4. The use of clickworkers addresses the uncertainty of new ideas by offering a vote-based evaluation mechanism.

Based on the above discussion, there are obvious benefits of using clickworkers (see Table 2); however, it remains unclear exactly how clickworkers contribute to the process of idea generation and evolution.

Table 2

Benefits of using clickworkers

Benefits of using clickworkers	**Underlying reasons**	**Illustrative studies**
External expertise	It opens organisational boundaries by enabling clickworkers to participate in idea generation at different times and in different locations.	Nickerson and Zenger (2004); O'Mahony and Ferraro (2007)
Large number of participants	It increases the cumulative results to be created from crowdsourcing and the opportunities for collaboration and competition.	Holmstrom and Henfridsson, (2006) Foss et al. (2016); Li et al. (2016); Kolbjornsrud (2017); Seidel et al. (2017)
Previously unknown external (new) participants	It increases the diversity of participants and ideas.	Sharma et al. (2002); Piezunka and Dahlander (2015); Schemmann et al. (2016)

Malone and Klein (2007) suggest that the use of clickworkers can be effectively applied in resolving systemic problems of vast complexity, such as the reduction of human-generated greenhouse gas emissions and global climate change, which is a pressing issue currently faced by humanity. The complexity of the problem requires engagement in effective collective ideation on a global scale. The use of clickworkers and the availability of the Internet have made it possible to combine the work of thousands of interested and knowledgeable participants in sharing ideas to achieve greenhouse gas reduction. Malone,

Laubacher and Dellarocas (2010) suggest clickworkers can be used for commercial purposes, but the use of clickworkers needs to be designed and managed to meet specific needs. They argue that clickworkers and technologies have not yet been used effectively, especially in the process of idea generation.

There is still a theoretical gap in the use of clickworkers. While research on idea generation online platforms has shown how ideas are created and modified, little is known about the evolution of ideas after they are created, and how clickworkers are involved in idea evolution. Figueroa and Pérez (2018) highlight the need to manage the process of collective work and acquire new ideas within the online ideation system. When an ideation project is underway on an ideation platform, they emphasise the need to determine the indicators of the quality of ideas and the progress made, of interactive editing, vote distribution or the valorisation (difference in number) or consistency (similarity in number) of edits and votes.

Bonabeau (2009) suggests three development trends in the use of clickworkers in online ideation. First, ideation platforms using clickworkers have performed better than theories can explain. Second, the use of clickworkers is better for idea generation than for idea evaluation. Third, there are two issues in the use of clickworkers in ideation platforms, namely, loss of control and the balance of diversity to similarity of ideas. The first point offers a positive reason for conducting further research in this area. The second point is arguable in that idea generation and idea evaluation cannot be separated and compared with each other in terms of efficiency. The created ideas need to be evaluated in terms of quality and diversity, where quality is evaluated by the ranking of ideas, while diversity is evaluated by the broadness of ideas that relates to the differences and similarities among ideas. The results of idea generation cannot be assessed without idea evaluation. A possible reason could be that the

use of clickworkers can help to gather a large number of ideas, but the purpose of using this approach is to get good ideas. Also, the results of idea evaluation are based on the quality of ideas offered as a result of idea generation. More importantly, as previously outlined, ideation is a process of collaboration through editing (generation) and competition through voting (evaluation). Thus, the ideation process is a 'duality' of collaboration and competition. Bonabeau's (2009) results point to the need to determine how to measure this duality and provide a motivation for the current study. The third point about the balance of diversity to similarity of ideas provides a future research direction; there is a need to look at agreements and disagreements in ideation.

Based on the discussion above, it is clear that there is a theoretical gap with regard to how ideas evolve after they are created and how clickworkers are involved in idea evolution. Theories of ideation can be further developed by determining how clickworkers are used most efficiently. McHugh et al. (2016) examined the performance of clickworkers in online ideation and proposed a multi-level conceptual model for the use of clickworkers, which includes individual and collective intelligence. By using agent-based simulations and case studies, they identified a positive relation between individual intelligence and ideation outcome quality. In addition, Yu et al. (2018) reviewed the use of clickworkers in ideation. They compared measurements and modelling methods with regard to the use of clickworkers; they suggest that future research needs to focus on how to optimise collective ideation activities among clickworkers rather on than the technology itself. Svobodová and Koudelková (2011) suggest that the use of clickworkers has played an important role in the fast-changing world of economy and business. They investigated the process of ideation in business, especially the nature of participant involvement. The use of clickworkers in ideation enables involvement in idea creation, editing and voting, so that initial ideas can retain their

initial concept until they are sharpened and finalised. They suggest that future research needs to focus on participants as networks in ideation. Then, clickworkers can be used more effectively by organisations to improve participant involvement in ideation, and the ideation outcomes can be achieved more efficiently.

To summarise, the use of clickworkers on online ideation platforms provides rich opportunities to study both the individual processes of idea generation and the collective participant activities of editing, ranking and voting, which contribute to idea evolution. At the same time, our knowledge about collective ideation activities among clickworkers in online ideation remains scarce (Malone and Klein, 2007; Malone et al., 2010; Lévy, 2010; Peters and Heraud, 2015). This has prompted calls for research on how to optimise collective ideation activities among clickworkers rather than on the technology itself (Aaltonen and Seiler, 2015; McHugh et al, 2016; Figueroa and Pérez, 2018). In sum, this study focuses on the inter-individual level of collective ideation activities; it aims to shed light on how ideas evolve after they are created and how clickworkers are involved in idea evolution. Based on the above discussion, this study proposes the research question: What is the influence of collective ideation activities on ideation outcomes?

2.3.2. Understanding participant involvement based on engagement

In this study, participant involvement focuses primarily on votes and edits. Ideas are created individually and presented and visualised through the use of text and pictures on online idea generation platforms (Dodgson et al., 2006). Each participant's idea competes with those of others through a voting process (Lindic et al., 2011; Majchrzak and Malhotra, 2013). Finally, ideas are ranked in order (Majchrzak and Malhotra, 2013). This process is considered a form of selection. Selection among ideas can increase the chances of a larger number of diverse

ideas evolving into a few better ideas (West and O'Mahony, 2008). However, ideas with too much novelty are difficult to understand and are less likely to be selected. Criscuolo et al. (2016) found that diversity in panel expertise led to an increased preference for idea novelty. In this study, clickworkers as a panel of selectors shape the evaluation of ideas and the degree of novelty. Therefore, this study focuses on participant involvement in the voting process.

Ideas are modified and improved through collaboration among participants (Lindic et al., 2011). Encouraging collaboration can increase the chance of idea recombination, which results in better ideas (Lakhani and Von Hippel, 2003; Von Hippel and Von Krogh, 2006). At the same time, collaboration in idea edits can bridge the knowledge of various sub-groups and increase the chance of idea combination (Nambisan and Baron, 2010). Since ideas are created individually, collaboration in idea edits can increase the chance of combining ideas into better ideas (Stieger et al., 2012). The effective use of clickworkers in online idea generation depends on how well participants collaborate on refining ideas (West and O'Mahony, 2008; Maciuliene and Skarzauskiene, 2011). Thus, the use of clickworkers and online idea generation platforms facilitate idea generation through a process of idea evolution rather than only idea creation.

After creation, ideas evolve through a process of development and modification. Idea evolution is a process that encourages collaboration in refining ideas. However, current research on online idea generation platforms emphasises the creation of ideas, not their evolution. Thus, research is needed on how ideas evolve after they are created. It is not clear how participants collaborate in idea evolution, and to what extent collaboration can influence the quality of ideas generated. It is necessary to investigate the relation between collaboration

and the quality of ideas generated. Therefore, this study focuses on how clickworkers edit ideas collectively.

The discussion above highlights a gap with regard to the evolution of ideas after they are created, and the involvement of clickworkers in idea evolution. This study addresses this gap by focusing on participants' activities and involvement in the online ideation process that comprises idea creation, editing, and voting. In particular, the focus is on how collective ideation activities among clickworkers influence the outcomes of online ideation. Participants' involvement in ideation is about involving not only known experts, but also inactive and isolated participants (Berg, 2016). Inactivity is defined as a situation in which people do not frequently engage in ideation activities (Jeppesen and Lakhani, 2010). Isolation is defined as a situation in which people are isolated in ideation activities by doing different things from the others (Jeppesen and Lakhani, 2010). Inactivity and isolation are defined in the general context of ideation rather than in the specific context of online ideation (Jeppesen and Lakhani, 2010). Thus, this study needs to identify inactivity and isolation in the context of online ideation, in particular, the clickworkers' setting. Since participants in this research are anonymous clickworkers, it is not possible to gauge their knowledge, expertise and values. Inactive and isolated participants usually have different values and levels of knowledge; therefore, the involvement of inactive and isolated participants can increase the chance of acquiring diverse ideas and combining them into creative ideas (Suh and Shin, 2010; Suh et al., 2011). Thus, inactivity and isolation of participants are identified as two influential factors that have an impact on idea quality.

For the purpose of this study, inactivity is defined as inactive in online ideation activities in terms of idea creation, editing and voting (Jeppesen and Lakhani, 2010). Studies have shown

how participants' inactivity can influence the results of ideation. Useful theories here include the theory of individual creative action and the knowledge brokering theory. The theory of individual creative action (Ford, 1996) suggests that idea generation consists of individual creative actions, which are the joint results of sense-making processes, motivation, and knowledge and skills. Participant inactivity can have a negative influence on the results of ideation. In the context of this study, online ideation platforms allow clickworkers to gradually generate content and react to the contributions made by other clickworkers. Idea quality is based on cumulative contributions from participants, thus, participants' inactivity can have a negative influence on the results.

To illustrate this, Aaltonen and Seiler (2015) investigated how past edits influence later editing activities by exploring detailed edit-level data from Wikipedia. They suggest that users' inactivity in the past can lead to significantly fewer editing activities in the future. The increase in the number of words in an article over an eight-year period can be 45 percent lower without users' cumulative contributions. Although this demonstrates the relationship between users' inactivity and the outcomes of using online ideation platforms, the popularity of the topics was not fully considered. The growth trends of Wikipedia content can be influenced by the popularity of the topics rather than by users' inactivity. This demonstrates the beneficial nature of collective intelligence platforms, as open content production environments enable the involvement of inactive participants. However, it is doubtful that a higher number of cumulative contributions in the past can lead to more editing activities in the future, since the growth trends of Wikipedia content can be influenced by the popularity of the topics. The significant gap here is that this analysis was conducted at the platform level by comparing the growth of each topic's content, rather than comparing each user's activities,

such as the frequency or number of each user's edits. Also, it is arguable that the quality of results cannot be measured by the number of words alone.

Other research in this area (e.g. Janssen, 2005; Hargadon, 2006; Hargadon and Bechky, 2006; Unsworth and Clegg, 2010) suggests that individual creative actions are too complex and challenging, so inactivity does not necessarily influence the results. Thus, whether inactivity can influence idea quality remains unclear, and the influence of inactivity needs to be studied. Considering online ideation consists of three major activities, idea creation, editing and voting (Majchrzak and Malhotra, 2013; Nakatsu et al., 2014), this study investigates inactive participants in these three activities.

Based on the discussion above, this study's position is that the presence of inactive participants can lead to lower-quality ideas. According to the discussion about collective activities are in idea generation online platforms in Section 2.1, there are three main activities: idea creation, editing, and voting. Thus, inactive participants in these three activities are considered as negative effects and this research proposes:

- **Hypothesis 1a:** Ideas voted by inactive participants tend to have lower idea quality.
- **Hypothesis 1b:** Ideas edited by inactive participants tend to have lower idea quality.

Isolation is defined as *isolated in ideation activities by doing different things from the others; it includes editing and voting on ideas which are not edited or voted on by the others* (Jeppesen and Lakhani, 2010). In other words, participants engage in ideation activities individually rather than collectively with other participants. Studies have shown the effect of participant isolation on the results of ideation. Specifically, isolated participants have a negative influence on idea quality (Vaast, 2007). Connectivity to participants and ideas is

important in idea generation (Vaast, 2007; Berg, 2016). Isolated participants can decrease the chance of getting creative ideas (Wagner and Majchrzak, 2006; Jeppesen and Lakhani, 2010; Foss et al., 2011), and can also reduce the activity of the other participants. However, less clear is whether the involvement of isolated participants can influence idea quality, and the extent of that influence (Lingo and O'Mahony, 2010; Roberts and Piller, 2016). Thus, it is necessary to explore whether, and to what extent, isolated participants have an influence on the results of online idea generation.

In the context of this study, the successful use of clickworkers on online ideation platforms usually provides non-hierarchical structures of connections among participants through web-based technologies (Rohrbeck et al., 2009). In this environment, ideas can be spread and clickworkers can exchange feedback quickly. Connectivity to isolated participants is the key structure of connections among participants and ideas in idea generation (Wagner and Majchrzak, 2006; Vaast, 2007; Berg, 2016; Foss et al., 2011). Thus, the contribution of isolated participants is a key factor influencing idea generation results. While most previous studies were not performed in the context of using clickworkers on ideation online platforms, it is reasonable to suspect that isolated participants can have a similar negative influence on idea quality, either by voting or editing ideas (Lingo and O'Mahony, 2010; Roberts and Piller, 2016). Thus, it is necessary to explore whether isolated participants can have negative influences on the results of online idea generation and the extent of these influences. Based on the discussion above, this research proposes:

- **Hypothesis 2a:** Ideas voted by isolated participants tend to have lower idea quality.
- **Hypothesis 2b:** Ideas edited by isolated participants tend to have lower idea quality.

2.3.3 Understanding participant involvement based on person's connectivity in the network

Creativity can be associated with a person's connectivity in networks (Mitali and Ingram, 2018), especially when the person occupies a position connecting others. For example, if two people both have the same connections in a network, they may have similar results in innovative works, such as ideation. If a person's contacts are all linked with each other, the ideas and information the person gets are likely to be the same. In contrast, if a person's contacts are not linked with each other, the person is likely to receive different ideas and information. This person may then perform better as a result of having a better source of ideas. Having connections to different information pools is an advantage in innovative works (Mitali and Ingram, 2018).

To measure connectivity, centralities are introduced. The term 'centralities' is defined as *the degree of a node's (for example, a person or an idea in this study) connectivity to the other nodes in a given network* (Borgatti, 2011). An idea with high centrality means that the idea is highly connected to the others by collective ideation activities in the network. High centralities are considered advantages in a network, as a network with high centralities usually has high connectivity (Borgartti, 2011; Burt, 2015). In contrast, isolation and inactivity are disadvantages in network connections, as a network with isolation and inactivity usually has low connectivity (Burt, 2015). Centralities also measure each idea's network structure instead of the number of votes or edits only. There are three common types of network advantages (as centralities): betweenness, closeness, and eigenvector centrality (Freeman, 1979; Borgatti, 2011). Each of them provides distinct measures about how an idea is connected with participants, which means the structure of voting and editing connections. This study focuses on betweenness for the reason that betweenness is considered a network

advantage (Borgatti, 2011) while closeness and eigenvector centrality are considered neutral.

Betweenness, i.e. *the extent of a node's power of connecting the others in a given network on the shortest path* (Freeman, 1979; Borgatti, 2011) is considered a network advantage. This research uses the betweenness centrality to reflect the shortest path of the collective ideation activities among ideas in online ideation, meaning the extent to which an idea is connected to (or otherwise disconnected from) others. Ideas with high betweenness are those that have contributions from participants who are also contributing to other ideas. Such a network location advantage can increase the chance of involving different participants, and then allowing a larger number of diverse ideas to evolve into a few better ideas (West and O'Mahony, 2008). The connectivity among participants' ideas is the key structure of collective ideation activities (Vaast, 2007; Berg, 2016). The interactionist theory of creativity (Woodman, Sawyer, and Griffin, 1993) suggests that collective idea generation results stem from complex interactions among individuals.

Further research in this area (Shalley et al., 2009; Yuan and Woodman, 2010; Zhou and Shalley, 2010) suggests that connectivity among participants' ideas can improve the results of collective ideation processes. Collective ideation activities cannot simply be measured as the number of collective ideation activities or improvement in capabilities, since it has been demonstrated that there is no direct relationship between input and output in idea generation (Perry-Smith, 2006; Perry-Smith and Mannucci, 2017). Thus, collective ideation activities require analysis to be carried out at a different level – the level representing the links among participants and ideas in idea generation. Network analysis can help to understand how participants are involved in collective idea generation. The network dyads between ideas and participants represent how participants connect with each other by contributing to the same

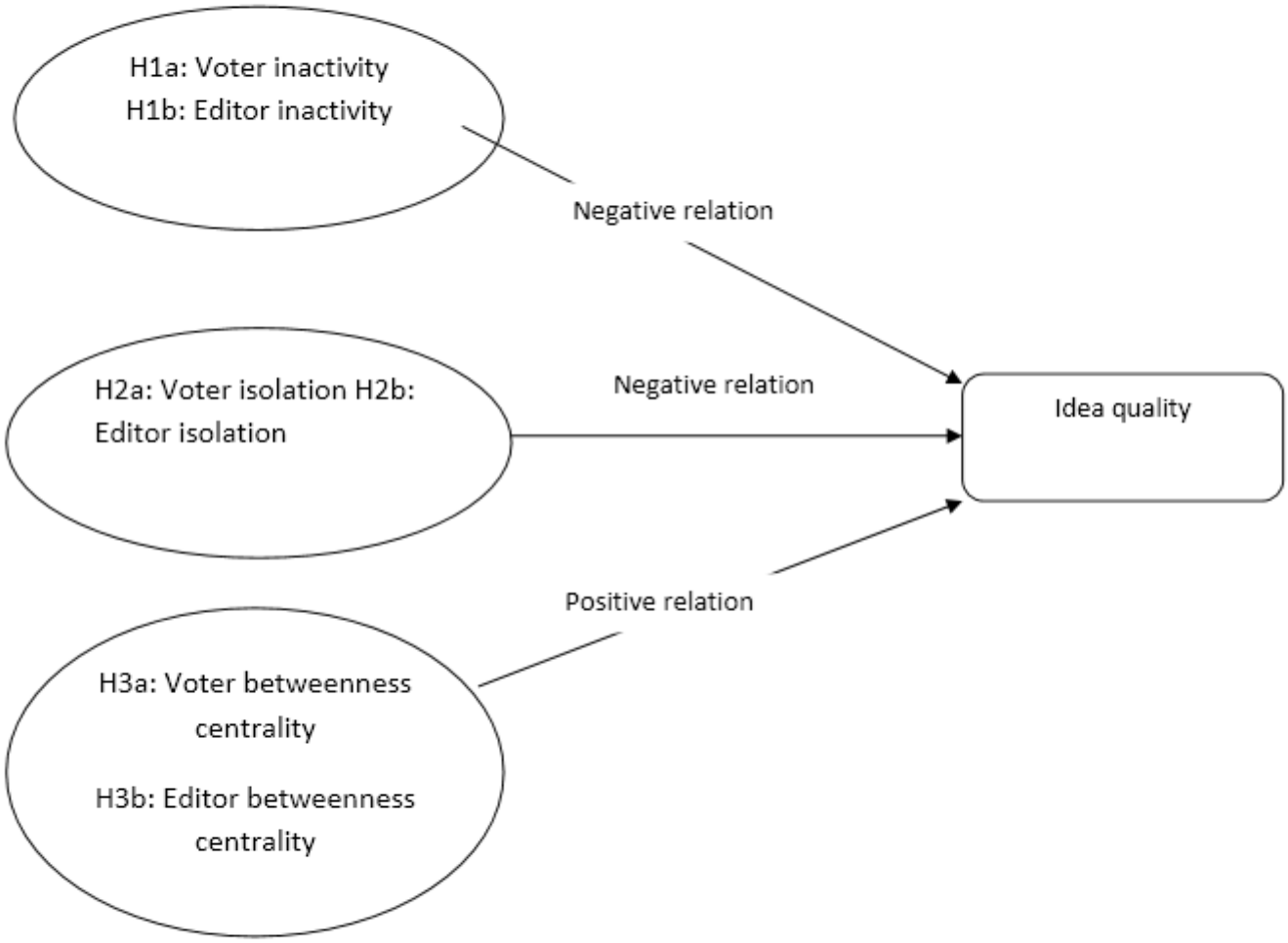
idea. Indeed, prior research showed that connectivity (contributing to the same idea) among participants is positively associated with idea quality in ideation (Björk and Magnusson, 2009). Thus, this study explores connectivity and its influence on idea quality. Based on the above discussion, this study argues that highly connected ideas in terms of votes and edits tend to be of higher quality.

- **Hypothesis 3a:** Highly connected ideas in voting networks tend to be of higher quality.
- **Hypothesis 3b:** Highly connected ideas in editing networks tend to be of higher quality.

To sum up, three groups of hypotheses need to be tested (see Figure 2). The first group of hypotheses (Hypothesis 1a and 1b) are about isolation. The second group (Hypothesis 2a and 2b) are about inactivity of participants. As discussed in the literature review, ideas with more contributions from isolated and inactive actors tend to have better idea quality. The third group of hypotheses (Hypothesis 3a and 3b) are about betweenness centralities. As suggested by the literature review, ideas with higher centralities tend to be of better quality.

Figure 2

Hypotheses



3. Methodology

The data consists of 408 participants and 216 ideas generated by them in two ideation projects, both collected on the Codigital ideation platform. This research performed network analysis on the collected data to generate networks in idea voting, editing and creation. Participants' isolation, inactivity and centralities were calculated in these networks. The research used regression modelling to test the influence of participants' isolation, inactivity and centralities on idea winning ratio.

3.1. Research setting

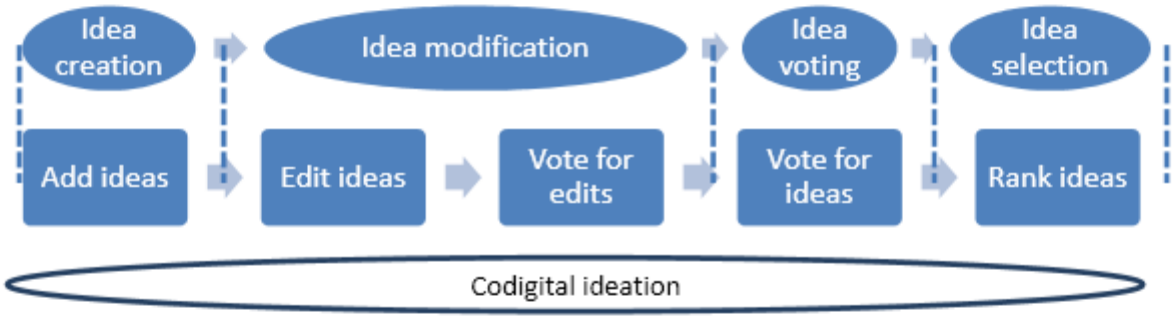
Codigital is an information technology company which provides a platform for large groups to create, edit and vote for ideas. As an idea generation online platform, Codigital's ideation tool consists of a user interface, a data and storage system and an artificial intelligence program. In idea generation projects, ideas are proposed online by individual participants, who then collaborate and compete to combine ideas into better ideas. For the purposes of this study, clickworkers from https://www.clickworker.com were used as participants.

In the Codigital ideation tool, idea creation is represented by 'add ideas', while idea modification is represented by 'edit ideas' and 'vote edits'. Idea voting is 'vote ideas' and idea selection is through 'rank ideas'. Thus, the Codigital ideation tool adheres to the description of an effective idea generation online platform based on the existing literature (see Figure 3). Previous research has suggested that ideation is simultaneously encouraging collaboration and competition through idea recombination, which leads to better idea quality (Lakhani and Von Hippel, 2003; Von Hippel and Von Krogh, 2006). Collaboration takes place in 'edit ideas' in the Codigital tool, where participants can edit each other's ideas.

Competition takes places in ‘vote edits’, ‘vote ideas’, and ‘rank. Edits and ideas are voted on, to finalise edits and rank ideas. Thus, the Codigital ideation tool is an effective idea generation online platform to encourage collaboration and competition in ideation. Further details of the Codigital ideation platform functions and interface are included in Appendix 2.

Figure 3

The Codigital ideation and its relationship with the literature: Creation-modification- voting-selection (adapted from Lindic, et al., 2011; Majchrzak and Malhotra, 2013; Nakatsu et al., 2014)



3.2. Data and variables

The data was provided by Codigitial from the ideation platform database about two completed projects. Table 3 shows the profile of these two ideation projects.

Table 3

Ideation project profiles

Project	**Number of participants**	**Number of ideas generated by participants**	**Number of votes on the generated ideas**	**Number of edits on the generated ideas**	**Duration**
Project 1: What should our global New Year resolutions be?	83	42	787	149	30–31 December 2016
Project 2: What measures would you recommend to ensure the safety of young people on social media?	325	174	4241	659	30–31 January 2019
	Total 408	**Total** 216	**Total** 5028	**Total** 808	

Data collection in network analysis seeks information about nodes and connections. In this study, the nodes are ideas created through idea generation. These nodes need to be discrete units (Parkhe et al., 2006). The nodes can be distinguished by ID. The connections are the collective ideation activities carried out by participants in idea generation, including editing and idea voting (Burt, 2015). Then, the collected data can be used to generate the network snapshots and carry out network analysis using the software Ucinet.

Three important points in the data structure need to be acknowledged here. First, voting was very active in these two successful projects. A total of 408 participants registered 6,272 votes in these two online ideation projects. Results show a high density of votes (12.67 votes per person in average in Project 1 and 16.06 votes per person in average in Project 2). Second, there was a significant difference between the top and bottom ideas in the number of votes received (see Table 3). This suggests that the top ideas and bottom ideas were clearly distinguished by votes. Third, the numbers of votes received for top ideas were very close (see Table 3). This suggests that there was competition in voting. This was also confirmed in the later competition in the voting section. Table 4 provides further information to support these three points.

Table 4

Summary of the ideation projects

Project 1: What should our global New Year resolutions be?	**Top 5 ideas (by number of votes received)**	**Votes received (total = 1052)**
	1. Find a way to end all wars throughout the world.	66
	2. Put an end to fake news and educate everyone to understand the agenda of newspapers, to help people make their own minds up rather than being brainwashed.	61
	3. Increase global medical research to eradicate killer diseases.	58
	4. Join with all countries to stop/reverse climate change.	57
	5. Be kind to one another.	54
	Bottom 5 ideas (by number of votes received)	**Votes received (total = 1052)**
	1. Live every day according to the values of respect, teamwork, excellence, responsibility and fairness, all while living ethically on a global scale. Together we can make it!	1
	2. Unite instead of fighting with each other.	2
	3. Cut down on the use of social media in every walk of life, and return to some form of old-fashioned communication.	3
	4. Find a way for humanity to exist on this earth forever.	3
	5. Ensure that those governments in denial of climate change be kept under continual pressure until they acknowledge the problem.	3

Project 2: What measures would you recommend to ensure the safety of young people on social media?	**Top 5 ideas (by number of votes received)**	**Votes received (total = 5220)**
	1. Require all accounts to be linked to a traceable person, ideally a parent, guardian, family member or teacher. Those people would have to approve any friends added. (Must provide verifiable address details.)	249
	2. Every account has to be verified with ID (or parents' ID) in order to link each account with a real person so finding trolls is a lot easier.	245
	3. More lessons in schools, college and university on how to use the Internet safely.	219
	4. Educate parents of the potential risks involved when their children use social media. Provide tools like filters for parents to use to monitor their social media behaviour.	192
	5. Have modified social media profiles for young people so that location/school/similar identifying information cannot be added (even if education fails, there is a physical barrier in place to prevent the publication of this information).	185
	Bottom 5 ideas (by number of votes received)	**Votes received (total = 5220)**
	1. There is more of a problem with children who do not have a 'real life' to balance the influence of social media. They won't take to heart comments by strangers online so much if they've had a hug or laugh with a hobby group or something in real life.	2
	2. Not encourage young children/teenagers to use the Internet and have phones/laptops. They should go outside more.	2
	3. Ban children from using social media networks.	2
	4. The young generation to be checked by parents.	2

	5. Create games like pantosauraus with catchy songs to teach kids about sexual harassment and other unwanted contact.	2

Independent variables

In order to test the proposed hypotheses, this section deals with measurement of the variables. For Hypotheses 1 and 2, the independent variables were isolation and inactivity. For Hypotheses 3, the independent variables were centralities including betweenness, closeness and eigenvector centrality. These network patterns are the independent variables in this research.

The first set of independent variables is explicit and can be measured by network analysis. Isolation measures the extent to which a node connects with the others in the network (Freeman, 1979; Borgatti, 2011). It is calculated by assessing the decrease in the number of network paths if the node is deleted in the voting and editing network respectively. Inactivity measures the connection density of a node's directly connected 'neighbours' (Freeman, 1979; Wasserman and Faust, 1994; Borgatti, 2011). It is calculated according to the number of connections a node's directly connected 'neighbours' have in the voting and editing network respectively. Isolation includes isolation in voting, editing and creation (see Table 3). Similarly, inactivity includes inactivity in voting, editing and creation.

The second set of independent variables refers to the network connectivity of participants or ideas, also known as centralities. Centralities provide measures about each person or idea's ego network structure; these can reflect the importance and prominence of each person or idea in a given network. Thus, this research uses centralities as independent variables. There are three centrality measures: betweenness, closeness and eigenvector centrality (Freeman, 1977; Borgatti, 2011). Each of them provides a distinct measure of how a person or idea is centrally located in a given network. Betweenness centrality is measured according to how many times a node connects two others as the shortest path in a given network (Freeman,

1979; Wasserman and Faust, 1994; Borgatti, 2011). As discussed previously, this measure can reflect the node's connection power in a network. A node's betweenness centrality is expressed by the number of shortest paths in the network passing through that person. Betweenness centrality in voting is calculated according to the number of shortest paths in the vote network passing through that idea. Closeness centrality measures a node's network distance from all others (Freeman, 1979; Wasserman and Faust, 1994; Borgatti, 2011). Closeness centrality is calculated according to the overall number of network paths an idea has, to reflect the proximity of an idea in the network. Eigenvector centrality measures a node's indirect connections in the network (Freeman, 1979; Wasserman and Faust, 1994; Borgatti, 2011). Eigenvector centrality is calculated according to the number of connections a node has to the well-connected nodes in the network. Similarly, editor and creator centralities are generated in editor and creator networks respectively. As discussed previously, these three centralities quantify 'the extent of being centrally located in a network' into numbers, then these numbers can be used in later regression modelling. Thus, this research uses centralities to reflect proximity and connectivity in networks.

Dependent variables

In order to measure idea quality, this research defines the dependent variable as each idea's winning ratio in voting as a proxy for idea quality. Unlike other options, including the number of received votes and idea ranking, ideas' winning ratios can be analysed to determine differences in idea quality. In contrast, the number of received votes is associated with the number of participants, and idea ranking is only an ordinal measure; these are not able to reflect the extent of differences in idea quality. The reason is that, in the Codigital ideation platform, ideas are presented for voting in pairs, and the software determines which pairs of ideas will appear to participants. To correct for potential idea selection bias by the

software (e.g. some ideas may show up for voting more often than others, and then get more votes), this study calculates each idea's winning ratio in voting instead, which represents idea quality. The winning ratio is the percentage of wins in idea-paired votes (Girotra et al., 2010; Kornish and Ulrich, 2011). It is calculated as the number of received votes divided by the number of appearances in the voting process.

The proposed research questions require an analysis of the relationships between network patterns and idea generation outcomes. In order to test these relationships, this research needs to measure both network patterns and idea generation outcomes at the idea level. Previous research (Amabile, 1997; Burt, 2015) has suggested each individual idea's quality can be aggregated to influence the idea generation project outcome. Thus, the data regarding each idea's winning ratio in voting can help to analyse the distribution of idea generation outcomes in each project's network. Thus, this research uses the winning ratio of ideas in the voting process as the dependent variable.

Control variables

Firstly, to control the project size difference (the difference in the number of participants and number of ideas generated), the data are normalised by deducting the minimum value of the variable, and then divided by the difference between the maximum value and the minimum value (Cronk, 2019). Then, in order to test the proposed hypotheses, control variables were used to rule out other influences on the online ideation outcomes. The first is the number of ideas created by the creator. This measures how many ideas a person has created as a means of assessing creator activity; this is to control that an active creator may create better ideas (Aaltonen and Seiler, 2015). It is calculated according to the number of ideas a creator has produced. The second is the number of edits. This reflects how many edits each idea has

received; the reason for using this variable is to control that better ideas may be those with more edits (Aaltonen and Seiler, 2015). It is calculated as the total number of edits on the idea. The third control variable is the number of votes, since this measures how many votes the idea has received (Aaltonen and Seiler, 2015). The reason for using this variable is to control the influence of the number of votes on the winning ratio. The fourth is idea appearance, which measures how many times the idea is shown in the paired-idea vote. This is to address the possibility that ideas appearing more often have a higher number of votes, which may influence the winning ratio. It is calculated as the number of appearances in paired-idea voting. The fifth control variable, edit engagement, measures the extent of edit participation (Camacho at al., 2019). This is to control the difference of edit participation between ideation projects, because the best ideas could be those that are the most heavily edited. It is calculated according to the total number of edits divided by the total number of participants in the ideation project. The sixth, vote engagement, measures the extent of voter participation (Camacho at al., 2019). This is to control the difference of voter participation between ideation projects. It is calculated by the total number of votes divided by the total number of participants in the ideation project. The seventh, size of the project, measures the scale of the ideation project (Boudreau et al., 2011); this study uses this variable to control the size difference between ideation projects. It is calculated according to the total number of participants in the project. Table 5 below summarises the measures as they relate to the hypotheses.

Table 5

Summary of measures and hypotheses

	Measures
Dependent variable: Winning ratio	Winning ratio is the percentage of wins in idea-paired votes (Girotra, Terwiesch, and Ulrich, 2010; Kornish and Ulrich, 2011). It is calculated as the number of received votes divided by the number of appearances in the voting process.
Hypothesis 1a: Ideas voted by inactive participants tend to have lower idea quality.	Inactivity measures the connection density of a node's directly connected 'neighbours' (Freeman, 1979; Wasserman and Faust, 1994; Borgatti, 2011). It is calculated according to the number of connections a node's directly connected 'neighbours' have in the voting and editing network respectively.
Hypothesis 1b: Ideas edited by inactive participants tend to have lower idea quality.	
Hypothesis 2a: Ideas voted by isolated participants tend to have higher idea quality.	Isolation measures the extent of a node connecting with the others in the network (Freeman, 1979; Wasserman and Faust, 1994; Borgatti, 2011). It is calculated according to the decrease in the number of network paths if the node is deleted in the voting and editing network respectively.
Hypothesis 2b: Ideas edited by isolated participants tend to have lower idea quality.	
Hypothesis 3a: Highly connected ideas in voting networks tend to be of higher quality.	Betweenness centrality measures how many times a node connects two others as the shortest path in a given network (Freeman, 1979; Wasserman and Faust, 1994; Borgatti, 2011). An idea's vote betweenness centrality is calculated according to the number of

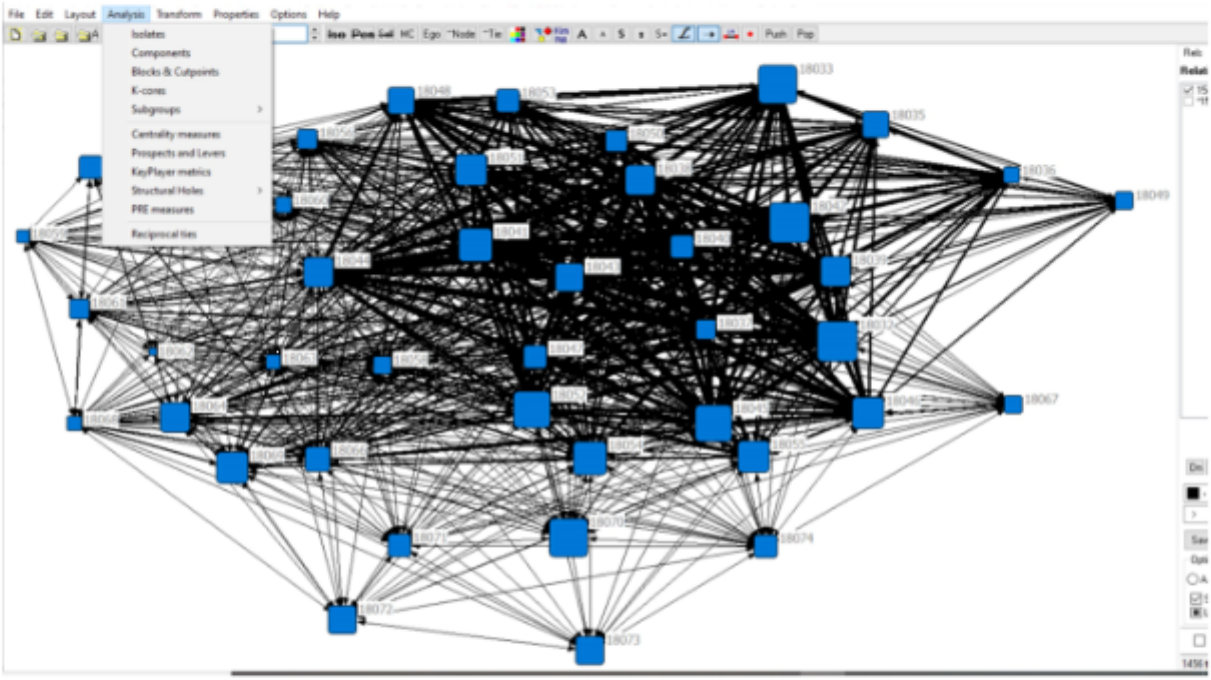
Hypothesis 3b: Highly connected ideas in editing networks tend to be of higher quality.	shortest paths in the voting network passing through that idea. Similarly, editor and creator betweenness centrality is generated in editor and creator networks respectively.

3.3. Data analysis

Network analysis is an approach to theorising about, representing and analysing social structures (Burt, 2015). Connections in idea generation can be analysed as networks by using the network analysis software package Ucinet (Burt, 2015). To answer the research questions, network data are analysed as snapshots. Network snapshots can present the overall structure of the network for each idea generation project. These network snapshots consist of two elements: (a) ideas as the actors (or nodes); and (b) collective ideation activities between individuals as the ties (or links). Complex networks usually have regular patterns in structures and dynamics, and these patterns can be observed from the network snapshots (See Figure 4).

Figure 4

Generating network using Ucinet



Network snapshots provide depictions of patterns of collective ideation activities among participants, which can be observed and analysed. It is important to analyse networks from snapshots, for example, by stages and structures. Each network is an ideation project with

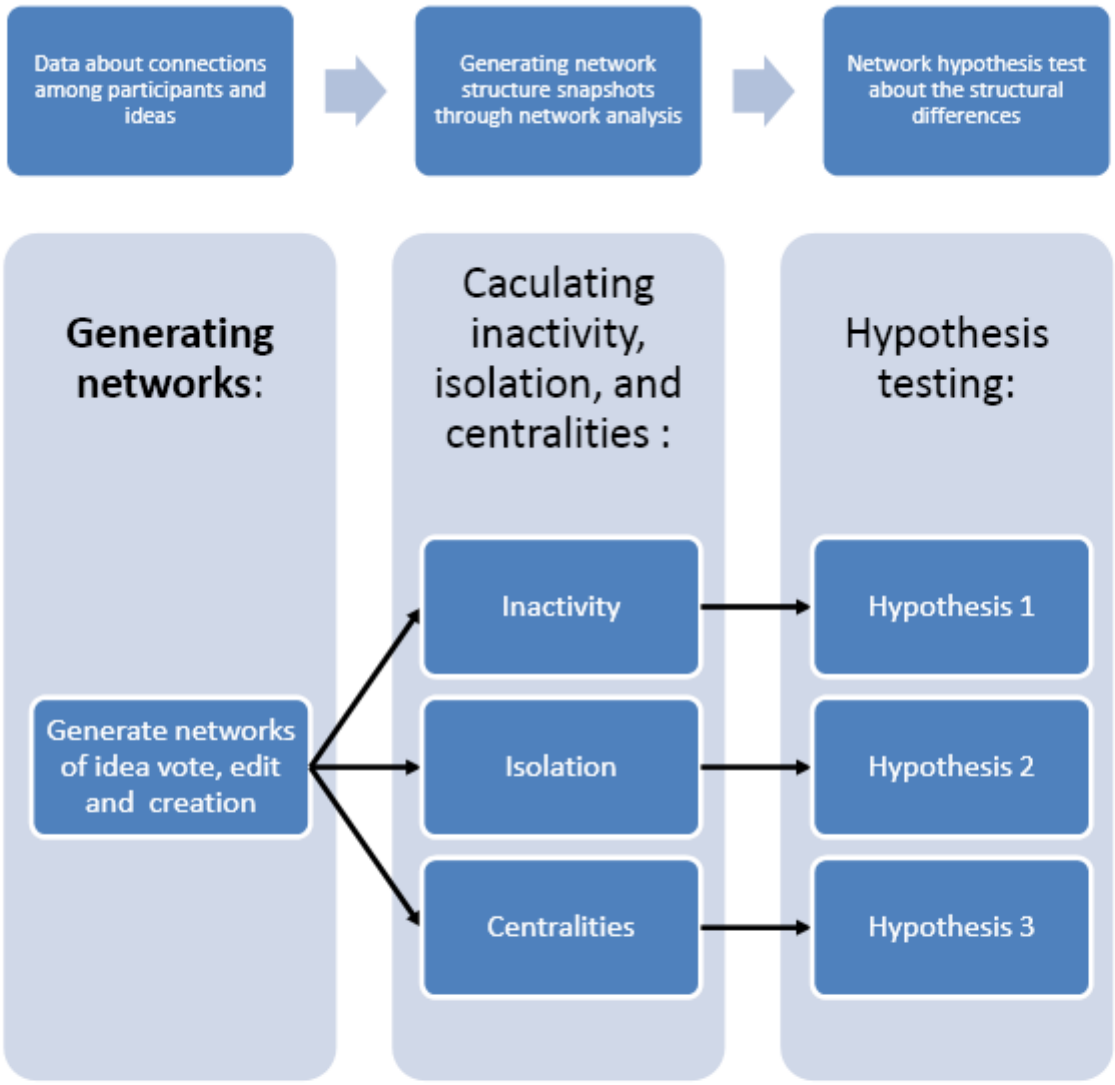
diverse ideas created by participants. To answer the research questions, this study uses centrality analysis. Centrality analysis can help to identify each participant's sub-network structure and network location, especially, to find out if a person is marginalised (loosely connected) or densely connected in a network. Then, network regression modelling can be performed between each idea's winning ratio in vote and their network isolation, inactivity and centralities to answer the research questions. Further details of how networks are generated and the calculation of variables are seen in Appendix 5.

Figure 5 summarises the key steps of this study's data analysis. Network regression can be performed in Ucinet by using the variables generated in network analysis. The reason is the normality of the data. This study chooses randomised permutation regression. Compared to another regression option, ordinary least squares regression (OLS), network data can be analysed more accurately by using randomised permutation regression. Randomised permutation regression can produce a better estimation of the model coefficients, especially for analysing networks which usually have some outliers in the data (Hanneman and Riddle, 2005). Network data with outliers can overly influence the regression modelling results in OLS regression due to the normality assumption (OLS regression assumes the data is normally distributed). Compared to OLS regression, randomised permutation regression is a better fit with network data distribution by testing the data against random distributions. This will provide more accurate analysis results and a robust model. Normality of the data distribution and goodness of fit in the modelling results are the other reasons for using randomised permutation regression to test network influences. First, in terms of normality of the data distribution, network data are binary data; 0 represents no connection between two nodes in a network and 1 represents a connection. Thus, the network data is not normally distributed. This can overly influence the regression modelling results. To resolve this issue,

this research chooses randomised permutation regression which does not have a normality assumption. Randomised permutation regression tests the data against random distributions rather than normal distribution to resolve the normality issue in the data (Hanneman and Riddle, 2005).

Figure 5

Key steps in data analysis for this study



4. Findings

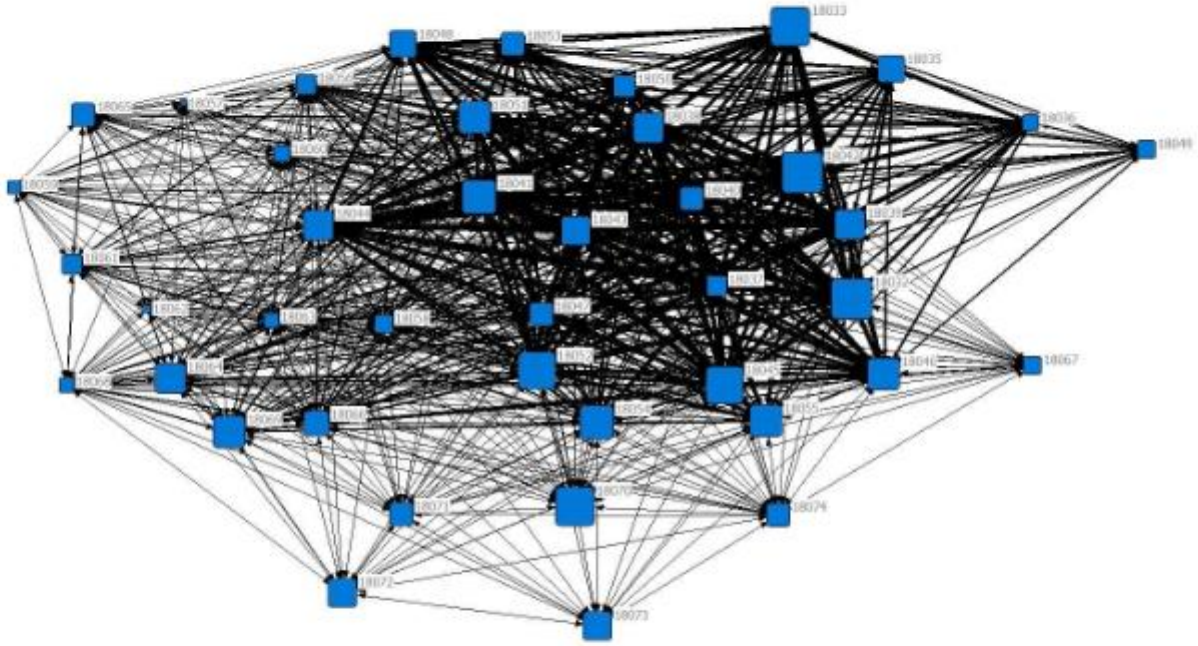
Figures 6 and 7 present the network snapshots in terms of the votes from all participants in each project. The nodes are ideas. The lines are votes by the same participants. The size of idea node represents the winning ration in vote. The bigger size is the more votes won for that idea. Similarly, the thickness of lines represents the number of votes submitted by the same participant.

Figure 6

Project 1 overall vote activities

Ideation topic: What should our global New Year resolutions be?

83 participants	42 ideas generated	1052 votes



Lines represent voted by the same participants, thinness represents number of votes by the same participants

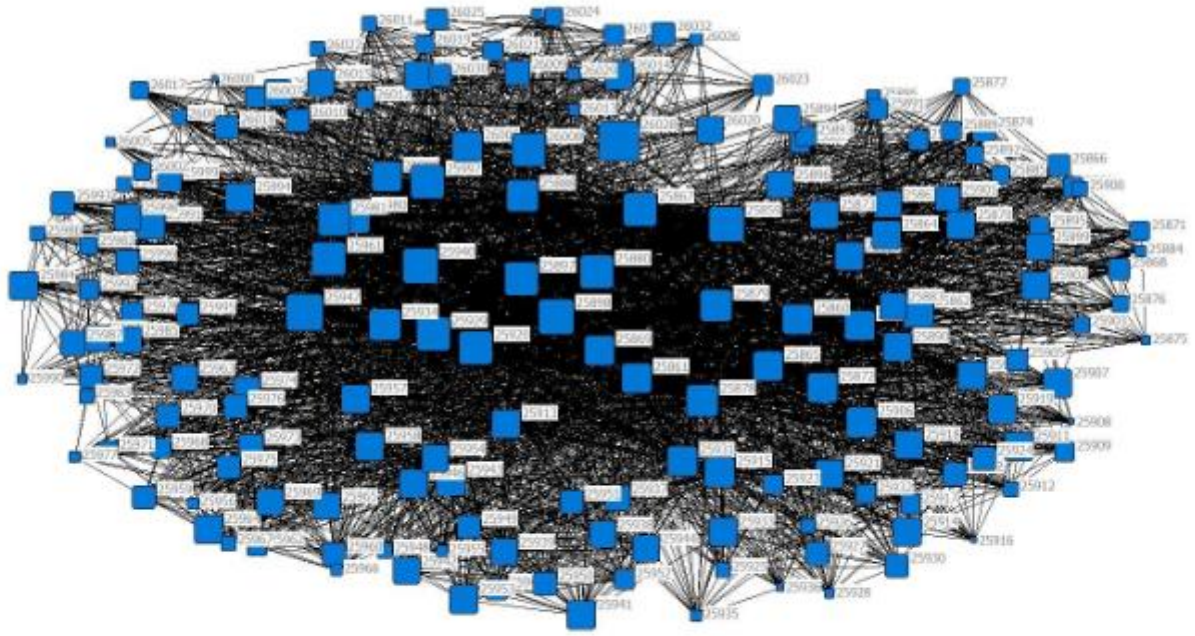
Idea, size represents winning ratio in vote

Figure 7

Project 2 overall vote activities

Ideation topic: What measures would you recommend to ensure the safety of young people on social media?

325 participants	174 ideas generated	5220 votes



Lines represent voted by the same participants, thinness represents number of votes by the same participants

Idea, size represents winning ratio in vote

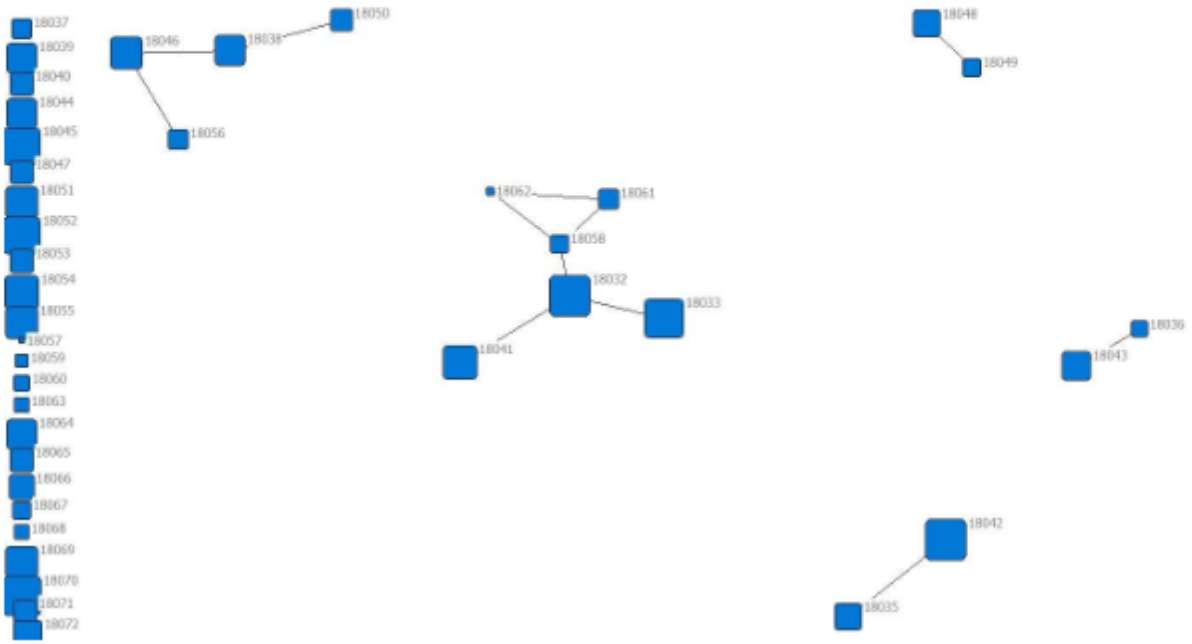
The purpose of generating these network snapshots is to identify isolation, inactivity and centralities in voting for later analysis. In the previous literature review, this study suggested that voting and editing are the two most essential activities in online ideation. Once ideas are created on an idea generation online platform, participants can improve them by suggesting modifications. Ideas can be modified and improved through collaborations among participants. Participants can edit their own ideas and collaborate to edit each other's ideas. Thus, this study also presents the findings about editing activities.

Figures 8 and 9 present the network snapshots for editing activities in each project. As in the previous snapshots, the nodes are ideas. Unlike in the previous snapshots, the lines are edits by the same participants rather than votes. The size of the idea node represents the winning ratio in vote. The thickness of lines represents the number of edits by the same participant. Table 6 provides a summary of the differences between the voting and editing networks.

Figure 8

Project 1 overall editing activities

Ideation topic: What should our global New Year resolutions be?



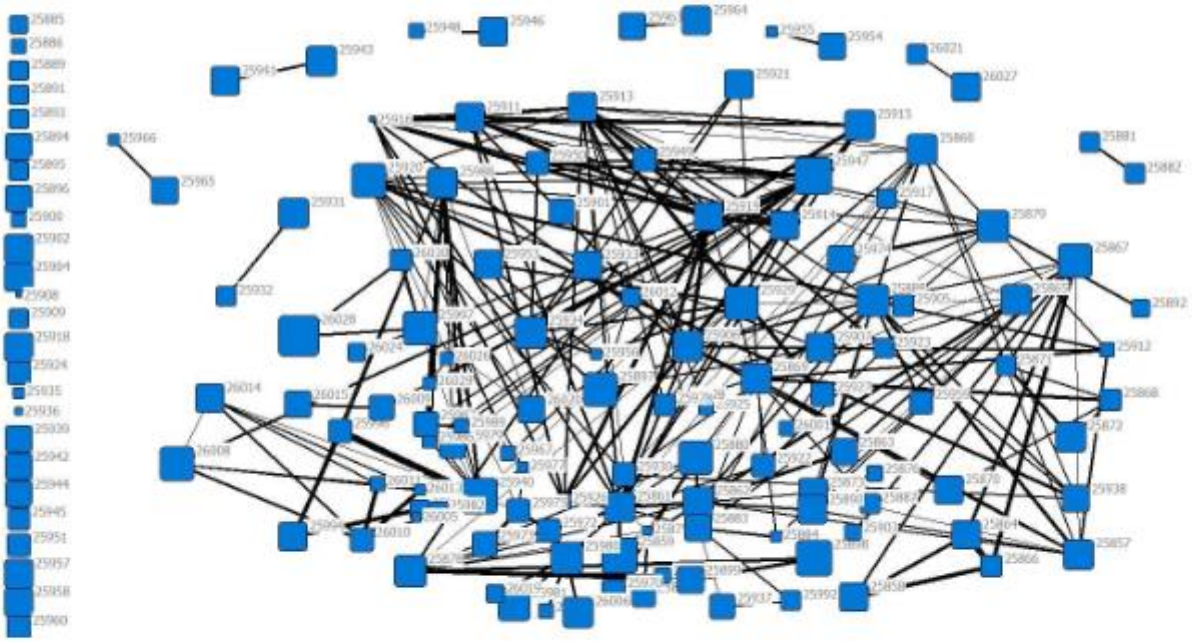
Lines represent edited by the same participants, thinness represents number of edits by the same participants

Idea, size represents winning ratio in vote

Figure 9

Project 2 overall editing activities

Ideation topic: What measures would you recommend to ensure the safety of young people on social media?



Lines represent edited by the same participants, thinness represents number of edits by the same participants

Idea, size represents winning ratio in vote

Table 6

Differences between voting and editing networks

Differences	Voting networks	Editing networks
Difference 1: Voting networks are more active than editing networks. This suggests there are more activities related to voting than to editing.	The vote networks consist of 5028 votes in total.	The edit networks consist of 750 edits in total.
Difference 2: Voting networks have better connectivity than editing networks. This suggests that co-voter for the same ideas are more likely than co-editors.	Each voting network is connected as one piece.	Each edit network is connected as several pieces.
Difference 3: There are disconnected ideas in editing networks. This suggests that some ideas are not co-edited.	There are no disconnected parts.	There are disconnected parts in the editing networks.

These snapshots also show that some ideas are connected by participants' editing activities. This means that multiple ideas are edited by the same participant. Stephen et al. (2016) suggest that when multiple ideas are edited by the same participant, this reduces the ranking of ideas in the use of the ideation platform. However, this study's results show that those ideas are likely to have a higher ranking position, since the big idea nodes (ideas with large numbers of votes) are edited by participants who also edited other ideas. On the other hand,

the small idea nodes are not edited by them. This could be the result of participants paying attention to the ideas of others and learning from them in online ideation projects (Schemmann et al., 2016).

These snapshots also show that some participants work individually and others work together in the editing process. Girotra et al. (2010) suggest participants working together generate better ideas than those working individually in online ideation projects. This study confirms this point, since the snapshots show that ideas with high ranking positions (big idea nodes) are edited by multiple participants. On the other hand, ideas with low ranking positions (small idea nodes) are edited individually. This is further discussed in the sections about regression modelling results. Tables 7 and 8 below show the descriptive statistics and correlation matrix.

Table 7

Descriptive statistics

	Minimum	Maximum	Mean	Std. Deviation
Votes	1	249	29.04	45.663
Appreances in Voting	2	421	58.27	78.537
Winning Ratio	.0952	.7000	.414015	.1233341
Edits	2	15	3.47	2.449
Size of Project	83	325	277.94	95.999
Editor Engagement	1.67	1.93	1.8794	.10314
Voter Engagement	12.6700	16.0600	15.400833	1.3447850
Voter Betweenness	.0000	1.0000	.138491	.2713998
Voter Isolation	.0714	1.0000	.169310	.1176878
Voter Inactivity	.0057	1.0000	.073825	.0878204
Editor Betweenness	.0000	1.0000	.056464	.1687109
Editor Isolation	.0042	.5000	.190917	.2167698
Editor Inactivity	.0042	1.0000	.388099	.4554822

Table 8

Correlation matrix

Labels in the rows: 1 Votes 2 Appreances inVote 3 Winning Ratio 4 Edits 5 Size of Project 6 Editor Engagement 7 Voter Engagement 8 Voter Betweenness 9 Voter Isolation 10 Voter Inactivity 11 Editor Betweenness 12 Editor Isolation 13 Editor Inactivity

Sig. (2-tailed), ** P<0.01, * p<0.05

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1.Votes	Pearson Correlation	1.00	.995**	.553**	.712**	0.11	0.04	0.04	0.04	.633**	.339**	-.267**	-.415**	-.336**	.502**	-.300**	.339**	-.295**	-.286**	0.00	-0.09	-0.01	-.176**
2.Appreances in Vote	Pearson Correlation	.995**	1.00	.510**	.716**	0.11	0.05	0.05	0.05	.623**	.340**	-.273**	-.413**	-.361**	.502**	-.307**	.356**	-.305**	-.296**	0.00	-0.09	-0.02	-.175**
3.Winning Ratio	Pearson Correlation	.553**	.510**	1.00	.427**	0.03	-.225**	-.225**	-.225**	.444**	.265**	-0.07	-.593**	-0.02	.288**	-0.06	.136*	-0.09	-0.08	0.00	-0.06	0.04	-0.09
4.Edits	Pearson Correlation	.712**	.716**	.427**	1.00	0.10	0.02	0.02	0.02	.429**	.460**	-.287**	-.335**	-.278**	.690**	-.350**	.436**	-.393**	-.351**	0.00	-0.09	0.05	-0.12
5.Size of Project	Pearson Correlation	0.04	0.05	-.225**	0.02	.165*	1.00	1.000**	1.000**	-.537**	-.398**	-.298**	-0.03	-.196**	0.00	-.314**	0.02	-.266**	-.298**	0.00	0.05	-.171**	-0.06
6.Editor Engagement	Pearson Correlation	0.04	0.05	-.225**	0.02	.165*	1.000**	1.00	1.000**	-.537**	-.398**	-.298**	-0.03	-.196**	0.00	-.314**	0.02	-.266**	-.298**	0.00	0.05	-.171**	-0.06
7.Voter Engagement	Pearson Correlation	0.04	0.05	-.225**	0.02	.165*	1.000**	1.000**	1.00	-.537**	-.398**	-.298**	-0.03	-.196**	0.00	-.314**	0.02	-.266**	-.298**	0.00	0.05	-.171**	-0.06

8.Voter Betweenness	Pearson Correlation	.633**	.623**	.444**	.429**	-0.05	-.537**	-.537**	-.537**	1.00	.197**	0.07	-.299**	-.180**	.375**	0.01	.232**	-0.01	0.02	0.00	-0.03	0.04	-0.03
9.Voter Isolation	Pearson Correlation	-.415**	-.413**	-.593**	-.335**	-0.08	0.03	0.03	0.03	-.299**	0.12	0.07	1.00	.526**	-.196**	.178**	-.147*	.233**	.226**	0.00	0.08	-0.02	.135*
10.Voter Inactivity	Pearson Correlation	-.336**	-.361**	-0.02	-.278**	-0.10	-.196**	-.196**	-.196**	-.180**	.230**	0.00	.526**	1.00	-.183**	.224**	-.160*	.265**	.269**	0.00	0.10	-0.06	0.13
11.Editor Betweenness	Pearson Correlation	.502**	.502**	.288**	.690**	.179**	0.00	0.00	0.00	.375**	.540**	-.226**	-.196**	-.183**	1.00	-.306**	.589**	-.272**	-.271**	0.00	-.204**	.178**	-.193**
12.Editor Isolation	Pearson Correlation	-.295**	-.305**	-0.09	-.393**	-.337**	-.266**	-.266**	-.266**	-0.01	-0.03	.811**	.233**	.265**	-.272**	.922**	-.389**	1.00	.975**	0.00	.315**	-.174*	.388**
13.Editor Inactivity	Pearson Correlation	-.286**	-.296**	-0.08	-.351**	-.345**	-.298**	-.298**	-.298**	0.02	-0.02	.788**	.226**	.269**	-.271**	.913**	-.388**	.975**	1.00	0.00	.332**	-.184**	.411**

In short, the results support the hypotheses relating to voter and editor inactivity (Hypotheses 1a and 1b); voter and editor isolation (Hypotheses 2a and 2b); and voter and editor betweenness (Hypotheses 3a and 3b). Table 9 shows the results of hypothesis testing.

Table 9 Collective Idea Generation on an Online Platform: An Analysis of User Interactions on a Clickworkers' Platform

Hypothesis testing results

Hypothesis	Hypothesis about	Supported, not supported, or the opposite supported
Hypothesis 1a	Negative influence of voter inactivity	Supported
Hypothesis 1b	Negative influence of editor inactivity	Supported
Hypothesis 2a	Negative influence of voter isolation	Supported
Hypothesis 2b	Negative influence of editor isolation	Supported
Hypothesis 3a	Positive influence of voter betweenness	Supported
Hypothesis 3b	Positive influence of editor betweenness	Supported

Table 10 shows the results of network regression modelling. This model suggests that ideas with high winning ratios (a) tend to have higher betweenness centralities in both votes and edits; (b) tend not to be voted for or edited by isolated voters; and (c) tend not to be voted for or edited by inactive voters. Also, this model has an R-square of 0.763 and an adjusted R-square of 0.756. This suggests the model is robust and can be used to explain the winning ratio. The R-square indicates how robust and accurate the overall model is. The higher the R-square, the more robust and accurate the overall model is (Wasserman and Faust; 1994; Hanneman and Riddle, 2005). In social sciences, models with an R-square above 0.7 can be considered robust and accurate (Wasserman and Faust; 1994; Hanneman and Riddle, 2005). Thus, the R-square of 0.763 indicates that the model is robust.

In contrast to the R-square, which measures the overall model, the P value indicates how robust each variable in the model is. The lower the P value, the more significant influence a

variable has (Wasserman and Faust; 1994; Hanneman and Riddle, 2005). In the findings presented in Table 9, voter betweenness, voter isolation and voter inactivity all have P values lower than 0.01. This suggests these variables are robust and have a significant influence, since each independent variable is lower than 0.05, which is considered the threshold for having a significant influence on the dependent variable (Wasserman and Faust; 1994; Hanneman and Riddle, 2005). All the other independent variables have P values higher than 0.05, which suggests they are not significantly correlated with the dependent variable of winning ratio in the voting process.

Table 10

Regression modelling results (dependent varible: winning ratio)

		Coefficients	Standard Error	Sig. (P value)
	Constant	1.153	.225	.000
Control variable	Votes	3.633	.001	.000
Control variable	Appreances in Vote	−2.523	.001	.000
Control variable	Edits	.038	.001	.396
Control variable	Voter Engagement	.009	.95	.695
Control variable	Editor Engagement	−.336	.098	.015
Control variable	Size of Project	.012	.093	.525
Hypothesis 1a	Voter Inactivity	.299	.063	.001
Hypothesis 1b	Editor Inactivity	−.125	.033	.005
Hypothesis 2a	Voter Isolation	−.365	.055	.003
Hypothesis 2b	Editor Isolation	−.233	.116	.009
Hypothesis 3a	Voter Betweenness	.283	.036	.008
Hypothesis 3b	Editor Betweenness	.292	.053	.006

	R-Square	Adjusted R-Square
	.763	.756

Sample Size 216

5. Discussion

As discussed in the Introduction, this study was motivated by three research gaps: the need to determine (a) the collective process in online ideation; (b) how ideas evolve based on collective processes; and (c) what factors affect the successful collective generation of ideas on online platforms. The following discussion focuses on how the findings of this study address these three gaps. Then, it highlights this study's contributions to theories and compares this study's findings with those of prior studies.

First, consistent with previous theories considering ideation as a process of creation, modification, voting and selection (Lindic, et al., 2011; Majchrzak and Malhotra, 2013; Nakatsu et al., 2014), this study investigates online ideation as consisting of 'idea creation', 'idea editing', 'idea voting' and 'idea ranking'. In particular, the Codigital ideation platform enables us to investigate the as-yet under-theorised process of collective ideation by studying participant interactions during idea editing, voting and ranking. A detailed description of the collective process in the Codigital ideation tool is attached in Appendix 2.

Second, this study contributes to understanding how ideas evolve based on collective processes. This study suggests that idea voting is influential on idea quality; in contrast, idea creation and editing are less likely to influence idea quality. The results do not show a significant correlation between inactive participants, isolated participants and centralities and winning ratios in idea editing and creation. Previous research (Stephen et al., 2016; Figueroa and Pérez, 2018) has suggested that idea creation, editing and voting are the key activities involving clickworkers and online platforms; therefore, inactivity, isolation and centralities in these three ideation activities are crucial to idea quality. However, this study suggests that only inactivity, isolation and centralities in idea voting can influence idea quality, while

inactivity, isolation and centralities in idea editing and creation do not. As previous research has suggested, ideation projects using online ideation platforms can face difficulties in motivating isolated and inactive participants and encouraging teamwork among active and inactive participants (Bonabeau, 2009). Similar to this finding about participants in editing activities, inactivity, isolation and centralities in editing activities are unlikely to contribute to ideation projects using online platform and clickworkers. Inactivity and isolation in editing are not significantly correlated with the winning ratio. Motivating participants relies on teamwork in idea generation, which clickworkers usually do not have (Wagner and Majchrzak, 2006; Jeppesen and Lakhani, 2010; Foss et al., 2011). Therefore, there is more competition among participants to reach higher idea rankings, and less collaboration since each clickworker works independently (Perry-Smith and Mannucci, 2017). Thus, this study suggests that when ideas evolve based on collective processes, idea editing and creation are unlikely to contribute to idea quality in ideation projects using online platforms and clickworkers.

Third, this study provides insights to what factors affect the successful collective generation of ideas in online platforms by specifying the types of ideation behaviours that are beneficial on a collective online ideation platform. In particular, this study suggests the following:

1. Ideas voted or edited by inactive participants tend to have lower winning ratios (the result supports Hypotheses 1a and 1b).
2. Ideas voted or edited by isolated participants tend to have lower winning ratios (the result supports Hypotheses 2a and 2b).
3. Ideas connecting other ideas in the network tend to have higher winning ratios (the result supports Hypotheses 3a and 3b).

First, participant inactivity in voting and editing is negatively associated with ideas' winning ratios in the voting process, which suggests a negative influence on the winning ratio. Unlike in prior research (Bonabeau, 2009; Stephen et al., 2016), this study treats participant inactivity as a continuous variable. Instead of setting a boundary determining how many connections participants should have in order to be labelled 'inactive' or 'not inactive', in this study a participant is either 'less inactive', 'more inactive', or 'equally inactive' compared to another participant. Then, regression modelling compares all the ideas' winning ratios in voting against their voters' level of activity. The results show that ideas voted on by inactive participants are more likely to have lower winning ratios in the voting process. This is the opposite to the proposed hypothesis, and suggests a negative influence of a participant's inactivity. Previous research considered inactive participants as having negative influences on idea quality (Bonabeau, 2009). This study confirms that inactive participants have negative effects on online idea quality. Inactive participants probably focus on their own ideas and make few contributions to other ideas. Stephen et al. (2016) suggest that highly active participants can improve the innovativeness of ideas, since they can be influenced by the other ideas they voted on and edited previously. Previous research also suggests that participants' involvement is about involving not only experts and active participants but also inactive participants who may provide different ideas (Vaast, 2007). Thus, this study suggests that inactive participants can negatively contribute to idea quality.

Second, participant isolation in voting and editing is negatively associated with ideas' winning ratios in voting, which suggests a negative influence on winning ratios. Ideas voted on by isolated participants tend to have higher idea quality. Similar to participant inactivity, this study treats participant isolation as a continuous variable, so that a participant is either 'less isolated', 'more isolated', or 'equally isolated' when compared to another participant.

The results show that ideas voted by isolated participants are more likely to have lower winning ratios. This is the opposite to the proposed hypothesis, suggesting a positive influence of participant isolation. Research (Suh and Shin, 2010; Suh et al., 2011) in the area of marginalised actors in ideation has suggested that isolated participants usually have different values and levels of knowledge; they have diverse ideas and combine them into better ideas in collective ideation, so that a positive influence of isolated participants is expected. However, this study's findings show that isolated participants tend to have negative effects. Also, previous research has suggested that the connectivity of participants relies on interpersonal connections (knowing each other) in idea generation (Wagner and Majchrzak, 2006; Jeppesen and Lakhani, 2010; Foss et al., 2011). Then, participants can be 'introduced' through interpersonal connections, so that their ideas can be combined with other participants' ideas into better ideas (Perry-Smith and Mannucci, 2017). However, there is usually a lack of interpersonal connections among clickworkers (Bonabeau, 2009); they are unlikely to know each other, with the result that participants are not able to be introduced and actively involved. Bonabeau (2009) also suggested this as an issue in using online ideation platforms: motivating participation and organising teamwork among active participants and isolated participants with diverse knowledge. Online ideation platforms have an advantage in connecting a large number of participants through the Internet; however, it is difficult to motivate them during online ideation projects. In this situation, some participants remain isolated, with the result that their knowledge is not able to be combined into ideas proposed by other participants. Isolated participants can reduce idea quality. In addition, participant isolation means participants are doing different things from the others. When it comes to idea voting, such isolated participants usually vote 'yes' for ideas voted 'no' by the others, so that these ideas usually have low winning ratios. Therefore, this study argues that isolated participants do not have a positive influence on idea quality; instead, they have a negative

influence.

Third, the betweenness centrality in voting and editing is positively associated with ideas' winning ratios in voting, which suggests a positive influence on winning ratios. Previous research (Björk and Magnusson, 2009; Camacho et al., 2019) suggested that participants with higher centralities can positively contribute to idea quality. However, in the context of ideation using online platform and clickworkers, this study suggests that only the betweenness centrality has a positive effect on idea quality. Previous research has suggested that the successful use of online platforms and clickworkers can provide non-hierarchical structures of teamwork among participants (Rohrbeck et al., 2009); however, such non-hierarchical structures usually lack leadership to motivate isolated participants (Vaast, 2007; Berg, 2016). In other words, there is no formal leader in these projects to activate and connect participants in ideation activities, even if these participants are unknown experts with different knowledge and value. Thus, this study suggests that only the betweenness centrality, (which represents connectivity between ideation activities) has a positive effect on idea quality. Table 11 highlights how this study contributes to previous theories in the area of the use of online ideation platform and summarises the discussion above.

Table 11

Contributions to previous theories in the use of online ideation platform

Related area	Contribution of this study
Related area: inactive participants	• Previous research (Bonabeau, 2009) suggested that ideation projects using online ideation platforms can face difficulties in motivating inactive participants and encouraging teamwork with them; therefore, inactive participants are considered to be negative influences. • This study argues that there is a positive effect of inactive participants on online idea quality.

Related area: isolated participants	• Previous research (Suh and Shin, 2010; Suh et al., 2011) suggested that isolated participants usually have different values and levels of knowledge, so that they can have diverse ideas and combine them into better ideas in collective ideation. • This study argues that there is a negative effect of isolated participants on idea quality.
Related area: centralities	• Previous research (Björk and Magnusson, 2009; Camacho at al., 2019) suggested that centralities of participants' ideas are positively associated with idea quality in ideation. • This study argues that only the betweenness centrality has a positive effect on idea quality.

To highlight how this study contributes to theories, this research compares the results with previous research in the use of online ideation platforms (see Table 12). Bonabeau (2009) studied the use of Web 2.0 and Wikipedia and suggested ideation projects using online ideation platforms can face difficulties in motivating marginalised participants and encouraging teamwork between active participants and marginalised participants. This study's findings confirm this point and add the positive effect of inactive participants and the negative effect of isolated participants. Malone et al. (2010) suggested the use of clickworkers needs to be managed and questioned the efficiency of using clickworkers. Also, Svobodová and Koudelková (2011) were concerned about the management of ideation in terms of clickworker involvement; they suggested future research needs to focus on clickworkers as networks in ideation. To improve understanding of the use of clickworkers, this study's findings suggest that the negative effect of marginalised participants can reduce the efficiency of using clickworkers. Figueroa and Pérez (2018) recommended future research into the key factors influencing the outcomes of using clickworkers and online platforms by a case study of Big-Data ecosystems. This study contributes to this by suggesting that isolated clickworkers in voting have a negative influence on the outcomes. In addition, Malone and Klein (2007) suggested that future research need to focus on platforms,

especially, how clickworkers and technologies work in collective ideation activities among participants in idea generation. Similarly, Lévy (2010) and Yu et al. (2018) highlighted the importance of voting and co-editing. To fill this gap, this study's findings add details about voting and co-editing among participants by presenting network snapshots. McHugh et al. (2016) suggested a positive relation between individual intelligence and ideation outcome quality and recommended that future research focus on inter-individual factors (collective ideation activities between individuals), which can influence the use of ideation outcomes. To fill this gap, this study analysed online ideation projects as networks at the inter-individual level and added marginalised participants as a negative inter-individual factors in of online idea generation. Camacho at al. (2019) suggested that the higher the clickworkers' activity intensity, the higher the quality of ideas; they concluded that the effect of clickworkers' activity intensity on idea quality is the most important factor. However, this study suggests that the number of edits has no effect and is not an important factor. Stephen et al. (2016) suggested that a high level of collaboration among clickworkers' activities can reduce the innovativeness of ideas. Similarly, Kornish and Ulrich (2011) suggested that a higher number of edits leads to similar ideas, and similar ideas are not usually the most valuable ones. In addition, Girotra et al. (2010) also suggested clickworkers working individually generate more and better ideas than those working together. However, this study suggests the opposite; the editing network snapshots show that co-editing has a positive effect on winning ratios in voting. Table 12 summarises the discussion above and compares this study's findings with those of previous research with regard to the use of online ideation platforms.

Table 12 Collective Idea Generation on an Online Platform:
An Analysis of User Interactions on a Clickworkers' Platform

Comparison of this study's findings and the previous research in the use of online ideation platform

Authors	**Cases/survey/ experiment**	**Points confirmed, added or argued by this study**
Bonabeau (2009)	The use of Web 2.0 and Wikipedia	**Related area: Marginalised participants** Bonabeau (2009) suggested ideation projects using online ideation platforms can face difficulty in motivating marginalised participants and in encouraging teamwork between active participants and marginalised participants. This study's findings confirm this point and add the negative effect of marginalised participants.
Malone, Laubacher and Dellarocas (2010)	Google, Wikipedia and Threadless	**Related area: Marginalised participants** Malone, Laubacher and Dellarocas (2010) suggested the use of clickworkers needs to be managed, and questioned the efficiency of using clickworkers. This study's findings suggest the negative effects of marginalised participants can reduce the efficiency of using clickworkers.
Svobodová and Koudelková (2011)	Pfitzer and IBM Lotus Domino	**Related area: Marginalised participants** Svobodová and Koudelková investigated the process of ideation in terms of clickworker involvement and motivation. Future research needs to focus on clickworkers as networks in the ideation process. This study analysed clickworkers' involvement as networks and suggests the negative effects of marginalised participants.
Figueroa and Pérez (2018)	The use of Big-Data ecosystem	**Related area: Voting and editing behaviour** Figueroa and Pérez (2018) recommended future research into the key factors

		influencing the outcomes of using clickworkers and online platforms. This study suggests that voting and editing have positive effects on the idea ranking positions.
Malone and Klein (2007)	Climate Collaboratorium and Cisco	**Related area: Voting and editing behaviour** Malone and Klein (2007) suggested that future research need to focus on platforms, especially, how clickworkers and technologies work in the process of idea generation. This study's findings add details about voting and editing behaviours in the process of idea generation.
Lévy (2010)	IEML (Information Economy MetaLanguage)	**Related area: Voting and editing behaviour** Lévy (2010) highlighted the importance of competition and collaboration. This study's findings add details about voting and editing behaviours among participants.
Yu, Chai and Liu (2018)	Zhihu, Douban and Netflix	**Related area: Voting and editing behaviour** Yu, Chai and Liu concluded that future research needs to focus on how to optimise the online ideation process rather than on the technology itself. This study suggests that voting and editing have positive effects on online ideation outcomes.
McHugh et al. (2016)	Google	**Related area: Voting and editing behaviour** McHugh et al. (2016) suggested a positive relation between individual intelligence and ideation outcome quality. Future research need to focus on the inter-individual factors (collective ideation activities between individuals) which can influence the use of ideation outcomes. This study's findings add voting and editing behaviours as positive factors in idea

		generation.
Boudreau and Lakhani (2013)	Apple, Kaggle and IBM	**Related area: Voting and editing behaviour** Boudreau and Lakhani (2013) suggested two approaches to the use of clickworkers in ideation: (a) competition; and (b) collaboration, This study adds that there are three types of centralities in voting and editing, and betweenness centrality has positive effects on online ideation outcomes.
Camacho et al. (2019)	Case 1: Longitudinal Classroom Experiment with Erasmus School of Economics Case 2: Study 2: ESE Innovation Tournament Case 3: Survey with 4,773 innovation managers	**Related area: Editing behaviour** Camacho et al. suggested that the higher clickworkers' activity intensity, the higher the quality of ideas. More importantly, the effect of clickworkers' activity intensity on idea quality is the most important factor. This study confirms that the number of edits has a positive effect. However, it is not the most important factor. The most important factor is competition in the voting process.
Stephen, Zubcsek and Goldenberg (2016)	Five experiments (ideation tasks) with 326 participants	**Related area: Editing behaviour** Stephen, Zubcsek and Goldenberg suggested that a high level of collaboration among clickworkers' activities can reduce the innovativeness of ideas. This study suggests the opposite: collaboration in editing has a positive effect on idea ranking positions.
Kornish and Ulrich (2011)	Experiment (ideation tasks) in classroom with 1,368 participants and	**Related area: Editing behaviour** Kornish and Ulrich suggested that the higher number of edits leads to similar ideas, and similar ideas are not usually the most valuable ones.

	279 ideas	This study suggests the opposite: the number of edits has a positive effect on idea ranking positions.
Girotra, Terwiesch and Ulrich (2010)	Experiment (ideation tasks) in classroom with 44 participants and 443 ideas	**Related area: Editing behaviour** Girotra, Terwiesch and Ulrich suggested clickworkers working individually generate more and better ideas than those working together. This study suggests the opposite: collaboration in editing has a positive effect on idea ranking positions.

6. Managerial implications

This study has two managerial implications for online ideation using clickworkers: what types of ideation behaviours are (a) beneficial and (b) not beneficial to idea quality. First, inactive participants and betweenness centralities in voting are beneficial to idea quality. This suggests that future online ideation projects should not control the number of votes from each participant. There is no need to set a minimum number of votes, since inactive participants can be very decisive about which idea they want to vote for. Also, findings about betweenness centralities suggest that future online ideation projects should pay attention to those ideas with a large portion of votes from the same participants. Ideas voted by the same group of participants are usually similar and have competition between each other during their evolution processes, so that they result in better quality.

Second, future online ideation projects should disregard isolated participants in voting, since ideas voted by them tend to be of lower quality. Also, future online ideation projects do not need to pay much attention to inactivity, isolation and centralities in idea creation and editing, since they do not influence idea quality. Previous research (Bonabeau, 2009) showed that online ideation platforms can face difficulties in motivating isolated and inactive participants. However, this study suggests that future ideation projects only need to pay attention to isolated and inactive participants in voting rather than in all collective ideation activities. Overall, future ideation projects do not need to pay attention to isolated participants, inactive participants, and centralities in idea creation and editing, since they do not influence idea quality.

7. Limitations and future research

This study only takes idea quality into account. The results of ideation can also be measured in different ways. For example, this study is not able to distinguish between radical and incremental changes in idea editing. Further research can be carried out to improve our model using semantic analysis. Each participant's contribution in editing can be compared with the changes they made to the ideas. This can provide further insight about editing activities. Another future research direction is related to the nature of ties in networks. Communication among participants can also be considered ties in networks. The information exchange ties can also be classified according to the content of information. For example, this can include editing-related information, proposing new ideas and confirmation of new ideas.

This study's findings are incapable of explaining why some online ideation projects fail. Ideation platforms bring together people with different knowledge and skills and facilitate the process of exchanging information and making ideation happen. Ideation project failure could be caused by excessive competition, certain kinds of changes, or simply just accidents. Game theory may help to resolve the first reason. The other two might still need input from qualitative research.

Future studies of ideation will generate more valuable insights regarding collective IT ideation, especially, the influences of isolation, inactivity and centralities on ideas generated within IT platforms. This study might have over-simplified complex ideation activities into the repetition of ideation creation, editing and voting. The content of each participant's action is not the same. There could a more detailed classification about activities with ideation creation, editing and voting.

Also, everyone in ideation projects contributes to the process of turning ideas into better ideas by using their knowledge and skills. Each participant's action adds new information to the ideas. The structure of the network is represented by numbers. Network data usually are binary data, containing only 0 and 1, with 0 representing no tie between people and 1 representing a tie. Any number between 0 and 1 can be considered a probability in modelling. Thus, it is possible to use stochastic modelling to predict a participant's next move with a large dataset.

Future research can also improve this study's model with more data across different sections and contexts. The results of this research show the importance of isolation, inactivity and centralities in two online ideation projects. These results can be further generalised with similar data from different business contexts. In terms of network theory, further research can cover the area of network dynamics, structure and influence.

It is possible to carry out a simulation of network dynamics with a large data set of over 1000 samples. This can offer a prediction of the sequence of ideation activities. This study used data based on two completed ideation projects. A large data set with more time points in the data can enable this kind of research. This will provide more detailed information about how ideas evolve. Network dynamics has been a cutting-edge area in network science, and a large data set can be used for analysis of network dynamics to determine more regular patterns of idea evolution.

8. Conclusion

Previous research has highlighted the importance of such factors as participants' experiences, intelligence and accessibility to idea-related information (Lingo and O'Mahony, 2010; Perry-Smith and Mannucci, 2017). These factors are limited to explaining individual idea creation rather than collective idea generation. However, idea generation results are usually decided by the collective evolution of ideas, for example, through idea editing and voting (Tsoukas, 2009; Anderson et al., 2014). These processes are increasingly enabled by IT platforms, but our knowledge about collectively generating ideas, as well as factors which influence these, has remained limited.

This study highlights theory gaps in (a) isolation and inactivity in participants' involvement, and (b) centralities in participants' involvement. This study is limited in that it focuses only on interpersonal factors and does not include technological factors and individual characteristics, such as creativity, motivation and experiences. Organisational IT and network-based information technologies enable new ideation practices within organisations (Vaast, 2007; Lindic et al., 2011) whereby a variety of previously distant participants are connected for the purpose of idea generation (Afuah and Tucci,2012; Suh et al., 2011; Perry-Smith and Mannucci, 2017). Idea generation IT platforms here not only provide online connections among participants, but also provide the environment. Collective ideation activities create social networks in idea editing and voting. However, the structures of these networks have not been considered in existing studies. Therefore, this research contributes to theories about the structures of collective ideation activities in online idea generation.

References

Aaltonen, A. and Seiler, S. 2015. Cumulative growth in user-generated content production: evidence from Wikipedia. *Management Science*. 62(7), pp. 2054–2069.

Afuah, A. and Tucci, C. L. 2012. Crowdsourcing as a solution to distant search. *Academy of Management Review*. 37(3), pp. 355–375.

Afuah, A. and Tucci, C. L. 2013. Value capture and crowdsourcing. *Academy of Management Review*. 38(3), pp. 457–460.

Anderson, N., Potočnik, K. and Zhou, J. 2014. Innovation and creativity in organizations. A state-of-the-science review, prospective commentary, and guiding framework. *Journal of Management*. 40, pp. 1297–1333.

Amabile, T. M. 1997. Motivating creativity in organizations: On doing what you love and loving what you do. *California Management Review*. 40, pp. 39–58.

Amabile, T. M. and Conti, R. 1999. Changes in the work environment for creativity during downsizing. *Academy of Management Journal*. 42, pp. 630–640.

Battistella, C. and Nonino, F. 2012. What drives collective innovation? Exploring the system of drivers for motivations in open innovation, Web-based platforms. *Information Research*. 17(1), pp. 17–31.

Berg, J. M. 2016. Balancing on the creative highwire: Forecasting the success of novel ideas

in organizations. *Administrative Science Quarterly.* 61(3), pp. 433–468.

Björk, J. and Magnusson, M. 2009. Where do good innovation ideas come from? Exploring the influence of network connectivity on innovation idea quality. *Journal of Product Innovation Management*. 26(6), pp. 662–670.

Bonabeau, E. 2009. Decisions 2.0: The power of collective intelligence. *MIT Sloan Management Review*. 50(2), pp. 45–66.

Borgatti, P. 2011. On network theory. *Organization Science.* 17, pp. 1–12.

Bothos, E., Apostolou, D. and Mentzas, G. 2009. Collective intelligence for idea management with Internet-based information aggregation markets. *Internet Research*. 19(1), pp. 26–41.

Boudreau, K, J., and Lakhani, K., R. (2009) How to manage outside innovation. *MIT Sloan Management Review,* 50: 69–76.

Boudreau, K., Lacetera, N. and Lakhani, K. R. 2011. Incentives and problem uncertainty in innovation contests: An empirical analysis. *Management Science.* 57, pp. 843–863.

Boudreau, K. J. and Lakhani, K. R. 2013. Using the crowd as an innovation partner. *Harvard Business Review.* 91(4), pp. 60–69, 140.

Brabham, D. C. 2013. *Crowdsourcing*. New York: Springer.

Brass, D. J., J. (2004). Taking Stock of Networks and Organizations: A Multilevel Perspective. *Academy of Management Journal,* 47(6): 795-817.

Burt, R. S. 2015. Reinforced structural holes. *Social Networks*. 43, pp. 149–161.

Camacho, N., Nam, H., Kannan, P. K. and Stremersch, S. 2019. Tournaments to crowdsource innovation: The role of moderator feedback and participation intensity. *Journal of Marketing*. 83(2), pp. 138–157.

Camison-Zornoza, C., Lapiedra-Alcamí, R., Segarra-Cipres, M., & Boronat-Navarro, M. (2004). A meta-analysis of innovation and organizational size. *Organization Studies*, 25:331-361.

Chen, G., Liu, C., & Tjosvold, D. (2005). Conflict management for effective top management teams and innovation in China. *Journal of Management Studies*, 42: 277-300.

Chesbrough, H. 2003. *Open innovation: The new imperative for creating and profiting from technology*. Boston: Harvard Business School Press.

Clegg, C., Unsworth, K., Epitropaki, O., & Parker, G. (2002). Implicating trust in the innovation process. *Journal of Occupational & Organizational Psychology,* 75: 409-422.

Cohen, W, M., and Levinthal, D, A. (1990) Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly* 35: 128–152.

Cohendet, P., & Simon, L. (2007). Playing across the playground: Paradoxes of knowledge creation in the videogame firm. *Journal of Organizational Behavior,* 28: 587-605.

Colbert, A., Yee, N., & George, G. (2016). The digital workforce and the workplace of the future. *Academy of Management journal, 59*(3), 731-739.

Cooper, R. G. and Edgett, S. J. 2007. *Generating breakthrough new product ideas: Feeding the innovation funnel*. Ancaster: Product Development Institute.

Criscuolo, P., Dahlander, L., Grohsjean, T. and Salter, A. 2016. Evaluating novelty: The role of panels in the selection of R&D projects. *Academy of Management Journal.* 60(2), pp. 433–460.

Cronk, B. C. 2019. *How to use SPSS®: A step-by-step guide to analysis and interpretation*. London: Routledge.

Damanpour, F. (1991). Organizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators. *Academy of Management Journal, 34*(3), 555-590.

Damanpour, F., & Schneider, M. (2006). Phases of the adoption of innovation in organizations: Effects of environment, organization and top managers. *British Journal of Management*, 17: 215-236.

Damanpour, F. (2010). An integration of research findings of effects of firm size and market competition on product and process innovations. *British Journal of Management*, 21: 996-

1010.

Dodgson, M., Gann, D. and Salter, A. 2006. The role of technology in the shift towards open innovation: The case of Procter & Gamble. *R&D Management*. 36(3), pp. 333–346.

Erez, M., & Nouri, R. (2010). Creativity: The influence of cultural, social, and work contexts. *Management and Organization Review,* 6: 351-370.

Estellés-Arolas, E., & González-Ladrón-De-Guevara, F. (2012). Towards an integrated crowdsourcing definition. *Journal of Information science*, *38*(2), 189-200.

Felin, T., Lakhani, K. R. and Tushman, M. L. 2017. Firms, crowds, and innovation. *Strategic Organization.* 15(2), pp. 119–140.

Felin, T., and Powell, T. (2016) Designing organizations for dynamic capabilities. *California Management Review* 58: 78–96.

Felin T and Zenger, T. (2014) Closed or open innovation? Problem solving and the governance choice. *Research Policy* 43: 914–925.

Figueroa, J. L. P. and Pérez, C. V. 2018. Collective intelligence: A new model of business management in the big-data ecosystem. *European Journal of Economics and Business Studies*. 4(1), pp. 201–212.

Fiol, C. M., & O'Connor, E. J. (2005). Identification in face-to-face, hybrid, and pure virtual

teams: Untangling the contradictions. *Organization Science, 16*(1), 19-32.

Ford, C. M. 1996. A theory of individual creative action in multiple social domains. *Academy of Management Review.* 21, pp. 1112–1142.

Foss, N, J., Frederiksen, L. and Rullani, F. 2016. Problem-formulation and problem-solving in self-organized communities: How modes of communication shape project behaviors in the free open-source software community. *Strategic Management Journal.* 37, pp. 2589–2610.

Foss, N. J., Laursen, K. and Pedersen, T. 2011. Linking customer interaction and innovation: The mediating role of new organizational practices. *Organization Science.* 22, pp. 980–999.

George, J. M. 2007. Creativity in organizations. *The Academy of Management Annals.* 1, pp. 439–477.

Gibson, C. B. and Gibbs, J. L. 2006. Unpacking the concept of virtuality: The effects of geographic dispersion, electronic dependence, dynamic structure, and national diversity on team innovation. *Administrative Science Quarterly.* 51(3), pp. 451–495.

Gilson, L. L., Maynard, M. T., Jones Young, N. C., Vartiainen, M., & Hakonen, M. (2015). Virtual teams research: 10 years, 10 themes, and 10 opportunities. *Journal of Management, 41*(5), 1313-1337.

Gilson, L. L., & Shalley, C. E. (2004). A little creativity goes a long way: An examination of teams' engagement in creative processes. *Journal of Management*, 30: 453-470.

Girotra, K., Terwiesch, C. and Ulrich, K. T. 2010. Idea generation and the quality of the best idea. *Management Science*. 56(4), pp. 591–605.

Goertzel, B. 2007. *Artificial general intelligence*. New York: Springer.

Greve, H. R. (2003). A behavioral theory of R&D expenditures and innovations: Evidence from shipbuilding. *Academy of Management Journal*, 46: 685-702.

Gulati, R., P. Puranam, and M. Tushman. (2012). Meta ‐ organization design: Rethinking design in interorganizational and community contexts. *Strategic management journal* 33 (6):571-586.

Hargadon, A. B. (2002). Brokering knowledge: Linking learning and innovation. *Research in Organizational behavior*, 24, 41-85.

Hargadon, A. B. 2006. Bridging old worlds and building new ones: Toward a microsociology of creativity. *Creativity and Innovation in Organizational Teams*. 23, pp. 199–216.

Hargadon, A. B. and Bechky, B. A. 2006. When collections of creatives become creative collectives: A field study of problem solving at work. *Organization Science*. 17, pp. 484–500.

Harvey, S. and Kou, C.-Y. 2013. Collective engagement in creative tasks. The role of evaluation in the creative process in groups. *Administrative Science Quarterly*. 58, pp. 346–386.

Holmstrom, H. and Henfridsson, O. 2006. Improving packaged software through online community knowledge. *Scandinavian Journal of Information Systems.* 18(1), pp. 2–23.

Hossain, M., & Islam, K. Z. (2015). Ideation through online open innovation platform: Dell IdeaStorm. *Journal of the Knowledge Economy*, *6*(3), 611-624.

Hossain, M., & Kauranen, I. (2015). Crowdsourcing: a comprehensive literature review. *Strategic Outsourcing: An International Journal*, *8*(1), 2-22.

Howe, J. 2006. The rise of crowdsourcing. *Wired Magazine.* 14(6), pp. 1–4.

Huang, Y., Vir Singh, P., & Srinivasan, K. (2014). Crowdsourcing new product ideas under consumer learning. *Management science*, *60*(9), 2138-2159.

Huizingh, E. K. R. E. 2011. Open innovation: State of the art and future perspectives. *Technovation*. 31(1), pp. 2–9.

Hülsheger, U. R., Anderson, N., & Salgado, J. F. (2009). Team-level predictors of innovation at work: A comprehensive meta-analysis spanning three decades of research. *Journal of Applied Psychology,* 94: 1128-1145.

Janssen, O. 2005. The joint impact of perceived influence and supervisor supportiveness on employee innovative behaviour. *Journal of Occupational and Organizational Psychology.* 78, pp. 573–579.

Jeppesen, L. B. and Lakhani, K. R. 2010. Marginality and problem-solving effectiveness in broadcast search. *Organization Science*. 21(5), pp. 1016–1033.

Jung, D. I., Chow, C., & Wu, A. (2003). The role of transformational leadership in enhancing organizational innovation: Hypotheses and some preliminary findings. *The Leadership Quarterly*, 14: 525-544.

Jung, D., Wu, A. , & Chow, C. W. (2008). Towards understanding the direct and indirect effects of CEOs' transformational leadership on firm innovation. *The Leadership Quarterly,* 19: 582-594.

Kanawattanachai, P., & Yoo, Y. (2007). The impact of knowledge coordination on virtual team performance over time. *MIS Quarterly*, 783-808.

Kanefsky, B., Barlow, N. G. and Gulick, V. C. 2001. Can distributed volunteers accomplish massive data analysis tasks? *Lunar and Planetary Science*. 1(1), pp. 32–38.

Kijkuit, B., & Van den Ende, J. (2007). The organizational life of an idea: Integrating social network, creativity and decision-making perspectives. *Journal of Management Studies, 44*(6), 863-882.

Kimble, C., Grenier, C. and Goglio-Primard, K. 2010. Innovation and knowledge sharing across professional boundaries: Political interplay between boundary objects and brokers. *International Journal of Information Management*. 30, pp. 437–444.

King, A. and Lakhani, K. R. 2013. Using open innovation to identify the best ideas. *MIT Sloan Management Review.* 55(1), pp. 41–69.

Kirkman, B. L., Rosen, B., Tesluk, P. E., & Gibson, C. B. (2004). The impact of team empowerment on virtual team performance: The moderating role of face-to-face interaction. *Academy of Management journal, 47*(2), 175-192.

Kolbjornsrud, V. 2017. Agency problems and governance mechanisms in collaborative communities. *Strategic Organization.* 15(2), pp. 141–173.

Kornish, L. J. and Ulrich, K. T. 2011. Opportunity spaces in innovation: Empirical analysis of large samples of ideas. *Management Science.* 57(1), pp. 107–128.

Lakhani, K. R. and Von Hippel, E. 2003. How open source software works: 'Free' user-to-user assistance. *Research Policy.* 32, pp. 923–943.

Leiponen, A. and Helfat, C, E. (2010). Innovation objectives, knowledge sources, and the benefits of breadth. *Strategic Management Journal* 31: 224–236.

Leonardi, P. M. (2007). Activating the Informational Capabilities of Information Technology for Organizational Change. *Organization Science, 18*(5), 813-831.

Leonardi, P., & Vaast, E. (2016). Social media and their affordances for organizing: A review and agenda for research. *Academy of Management Annals,* 15(1), 01-44.

Lévy, P. 2010. From social computing to reflexive collective intelligence: The IEML research program. *Information Sciences*. 180(1), pp. 71–94.

Li, M., Kankanhalli, A. and Kim, S. H. 2016. Which ideas are more likely to be implemented in online user innovation communities? An empirical analysis. *Decision Support Systems*. 84, pp. 28–40.

Lindic, J., Baloh, P., Ribiere, V. M. and Desouza, K. C. 2011. Deploying IT for organizational innovation. *International Journal of Information Management*. 31(2), pp. 183–188.

Lingo, E. L. and O'Mahony, S. 2010. Nexus work: Brokerage on creative projects. *Administrative Science Quarterly*. 55, pp. 47–81.

Litchfield, R. C. and Gilson, L. L. 2013. Curating collections of ideas: Museum as metaphor in the management of creativity. *Industrial Marketing Management*. 42, pp. 106–112.

Locke, K., & Golden-Biddle, K. (1997). Constructing opportunities for contribution: Structuring intertextual coherence and "problematizing" in organizational studies. *Academy of Management journal, 40*(5), 1023-1062.

Maciuliene, M. and Skarzauskiene, A. 2011. Evaluation of co-creation perspective in networked collaboration platforms. *Journal of Business Research*. 69(11), pp. 4826–4830.

Mainemelis, C. (2010). Stealing fire: Creative deviance in the evolution of new ideas.

Academy of Management Review, 35(4), 558-578.

Majchrzak, A., Cooper, L. P., & Neece, O. E. (2004). Knowledge Reuse for Innovation. *Management Science, 50*(2), 174-188.

Majchrzak, A. and Malhotra, A. 2013. Towards an information systems perspective and research agenda on crowdsourcing for innovation. *The Journal of Strategic Information Systems*. 22(4), pp. 257–268.

Malhotra, A., & Majchrzak, A. (2014). Managing crowds in innovation challenges. *California Management Review, 56*(4), 103-123.

Malone, T. W., Laubacher, R. and Dellarocas, C. 2010. The collective intelligence genome. *MIT Sloan Management Review*. 51(3), pp. 21–38.

Malone, T. W. and Klein, M. 2007. Harnessing collective intelligence to address global climate change. *Innovations: Technology, Governance, Globalization*. 2(3), pp. 15–26.

Marks, M. A., Mathieu, J. E., & Zaccaro, S. J. (2001). A Temporally Based Framework and Taxonomy of Team Processes. *Academy of Management Review, 26*(3), 356-376

Martins, L. L., Gilson, L. L., & Maynard, M. T. (2004). Virtual teams: What do we know and where do we go from here? *Journal of Management, 30*(6), 805-835.

McHugh, K. A., Yammarino, F. J., Dionne, S. D., Serban, A., Sayama, H. and Chatterjee, S.

2016. Collective decision making, leadership, and collective intelligence: Tests with agent-based simulations and a field study. *The Leadership Quarterly*. 27(2), pp. 218–241.

McMillan, C. and Overall, J. 2016. Wicked problems: Turning strategic management upside down. *Journal of Business Strategy*. 37(1), pp. 34–43.

Mitali, B. and Ingram, P. L. 2018. Fame as an illusion of creativity: Evidence from the pioneers of abstract art. *HEC Paris Research Paper No. SPE-2018-1305, Columbia Business School Research Paper*, pp. 18–74.

Mok, A., & Morris, M. W. (2010). Asian-Americans' creative styles in Asian and American situations: Assimilative and contrastive responses as a function of bicultural identity integration. *Management and Organization Review*, 6: 371-390.

Morris, M. W., & Leung, L. (2010). Creativity East and West: Perspectives and parallels. *Management and Organization Review,* 6: 313-327.

Morschheuser, B., Hamari, J., Koivisto, J. and Maedche, A. 2017. Gamified crowdsourcing: Conceptualization, literature review, and future agenda. *International Journal of Human-Computer Studies*. 106, pp. 26–43.

Mount, M., & Martinez, M. G. (2014). Social media: A tool for open innovation. *California Management Review, 56*(4), 124-143.

Nakatsu, R. T., Grossman, E. B. and Iacovou, C. L. 2014. A taxonomy of crowdsourcing

based on task complexity. *Journal of Information Science.* 40(6), pp. 823–834.

Nambisan, S. and Baron, R. A. 2010. Different roles, different strokes: Organizing virtual customer environments to promote two types of customer contributions. *Organization Science.* 21(2), pp. 554–572.

Neisser, U. 1979. The concept of intelligence. *Intelligence.* 3(3), 217–227.

Nickerson, J. A. and Zenger, T. R. 2004. A knowledge-based theory of the firm: The problem-solving perspective. *Organization Science.* 15, pp. 617–622.

O'Mahony, S. and Ferraro, F. 2007. The emergence of governance in an open source community. *Academy of Management Journal.* 50, pp. 1079–1106.

Parkhe, A., Wasserman, S. and Ralston, D. A. 2006. New frontiers in network theory development. *Academy of Management Review.* 31(3), pp. 560–568.

Perry-Smith, J. E. 2006. Social yet creative: The role of social relationships in facilitating individual creativity. *Academy of Management Journal*. 49, pp. 85–101.

Perry-Smith, J., & Shalley, C. E. (2003). The social side of creativity: A static and dynamic social network perspective. *Academy of Management Review*, 28: 89-106.

Perry-Smith, J. E. and Mannucci, P. V. 2017. From creativity to innovation: The social network drivers of the four phases of the idea journey. *Academy of Management Review*. 42(1), pp. 53–79.

Peters, M. A. and Heraud, R. 2015. Toward a political theory of social innovation: collective intelligence and the co-creation of social goods. *Journal of Self-Governance & Management Economics*. 3(3), 83-98.

Phelps, C., Heidl, R., & Wadhwa, A. (2012). Knowledge, networks, and knowledge networks: A review and research agenda. *Journal of Management, 38*(4), 1115-1166.

Piezunka, H. and Dahlander, L. 2015. Distant search, narrow attention: How crowding alters organizations' filtering of suggestions in crowdsourcing. *Academy of Management Journal.* 58(3), pp. 856–880.

Poetz, M. K., & Schreier, M. (2012). The value of crowdsourcing: can users really compete with professionals in generating new product ideas? *Journal of Product Innovation Management, 29*(2), 245-256.

Raja, U., & Johns, G. (2010). The joint effects of personality and job scope on in-role performance, citizenship behaviors and creativity. *Human Relations*, 63: 981-1005.

Roberts, D. L. and Piller, F. T. 2016. Finding the right role for social media in innovation. *MIT Sloan Management Review.* 57(3), pp. 41–66.

Rohrbeck, R., Holzle, K. and Gemunden, H. G. 2009. Opening up for competitive advantage-How Deutsche Telekom creates an open innovation ecosystem. *R&D Management.* 39(4), pp. 420–430.

Rosing, K., Frese, M., & Bausch, A. (2011). Explaining the heterogeneity of the leadership innovation relationship: Ambidextrous leadership. *The Leadership Quarterly,* 22: 956-974.

Rouhani, S., Ashrafi, A., Zare Ravasan, A. and Afshari, S. 2016. The impact model of business intelligence on decision support and organizational benefits. *Journal of Enterprise Information Management*. 29(1), pp. 19–50.

Schemmann, B., Herrmann, A. M., Chappin, M. M. and Heimeriks, G. J. 2016. Crowdsourcing ideas: Involving ordinary users in the ideation phase of new product development. *Research Policy.* 45(6), pp. 1145–1154.

Schroeder, R.G., Van de Ven, A.H., Scudder, G.D., and Polley, D. (2000). The Development of Innovation Ideas. In: *Research on the Management of Innovation*, The Minnesota Studies, ed. A.H. Van de Ven, H.L. Angle, and M.S. Poole. Oxford: Oxford University Press, 107–34.

Seidel, V. P., Langner, B. and Sims, J. 2017. Dominant communities and dominant designs: Community-based innovation in the context of the technology life cycle. *Strategic Organization.* 15(2), pp. 220–241.

Shalley, C. E., Gilson, L. L. and Blum, T. C. 2009. Interactive effects of growth need strength, work context, and job complexity on self-reported creative performance. *Academy of Management Journal.* 52, pp. 489–505.

Shalley, C. E., Zhou, J. and Oldham, G. R. 2004. The effects of personal and contextual

characteristics on creativity: Where should we go from here? *Journal of Management*. 30, pp. 933–958.

Sharma, S., Sugumaran, V. and Rajagopalan, B. 2002. A framework for creating hybrid-open source software communities. *Information Systems Journal.* 12(1), pp. 7–25.

Shin, S. J., & Zhou, J. (2003). Transformational leadership, conservation, and creativity: Evidence from Korea. *Academy of Management Journal,* 46: 703-714.

Simula, H. and Ahola, T. 2014. A network perspective on idea and innovation crowdsourcing in industrial firms. *Industrial Marketing Management.* 43(3), pp. 400–408.

Somech, A. (2006). The Effects of leadership style and team process on performance and innovation in functionally heterogeneous teams. *Journal of Management*, 32: 132-157.

Spaeth, S., von Krogh, G., & He, F. (2014). Research note-Perceived firm attributes and intrinsic motivation in sponsored open source software projects. *Information Systems Research, 26*(1), 224-237.

Stephen, A. T., Zubcsek, P. P. and Goldenberg, J. 2016. Lower connectivity is better: The effects of network structure on redundancy of ideas and customer innovativeness in interdependent ideation tasks. *Journal of Marketing Research.* 53(2), pp. 263–279.

Stieger, D., Matzler, K., Chatterjee, S. and Ladstaetter-Fussenegger, F. 2012. Democratizing strategy: How crowdsourcing can be used for strategy dialogues. *California Management*

Review. 54(4), pp. 44–68.

Suh, A. and Shin, K.-S. 2010. Exploring the effects of online social ties on knowledge sharing: A comparative analysis of collocated vs dispersed teams. *Journal of Information Science*. 36(4), pp. 443–463.

Suh, A., Shin, K.-S., Ahuja, M. and Kim, M. S. 2011. The influence of virtuality on social networks within and across work groups: A multilevel approach. *Journal of Management Information Systems*. 28(1), pp. 351–386.

Svobodová, A. and Koudelková, P. 2011. Collective intelligence and knowledge management as a tool for innovations. *Economics and Management*. 16, pp. 942–946.

Terwiesch, C., & Xu, Y. (2008). Innovation contests, open innovation, and multiagent problem solving. *Management Science, 54*(9), 1529-1543.

Thorpe, R., Holt, R., Macpherson, A., & Pittaway, L. (2005). Using knowledge within small and medium-sized firms: A systematic review of the evidence. *International Journal of Management Reviews, 7*(4), 257-281.

Tierney, P., & Farmer, S. M. (2002). Creative self-efficacy: Its potential antecedents and relationship to creative performance. *Academy of Management Journal*, 45: 1137-1148.

Tsoukas, H. 2009. A dialogical approach to the creation of new knowledge in organizations. *Organization Science*. 20, pp. 941–957.

Unsworth, K. L. and Clegg, C. W. 2010. Why do employees undertake creative action? *Journal of Occupational and Organizational Psychology.* 83, pp. 77–99.

Vaast, E. (2004). O brother, where are thou? From communities to networks of practice through intranet use. *Management Communication Quarterly, 18*(1), 5-44.

Vaast, E. 2007. What goes online comes offline: Knowledge management system use in a soft bureaucracy. *Organization Studies.* 28(3), pp. 283–306.

Van De Vrande, V., Vanhaverbeke, W. and Gassmann, O. 2010. Broadening the scope of open innovation: Past research, current state and future directions. *International Journal of Technology Management.* 52(3/4), pp. 231–235.

Von Hippel, E., & Von Krogh, G. v. (2003). Open source software and the "private-collective" innovation model: Issues for organization science. *Organization Science*, 14(2), 209-223.

Von Hippel, E. and Von Krogh, G. 2006. Free revealing and the private-collective model for innovation incentives. *R&D Management.* 36(3), pp. 295–306.

Wagner, C. and Majchrzak, A. 2006. Enabling customer-centricity using wikis and the wiki way. *Journal of Management Information Systems.* 23(3), pp. 17–43.

Wang, P., & Rode, J. C. (2010). Transformational leadership and follower creativity: The

moderating effects of identification with leader and organizational climate. *Human Relations*, 63: 1105-1128.

Watts, D., & Strogatz, S. (1998). Collective dynamics of "small-world" networks. *Nature, 393*(6684), 440-442.

West, J. and O'Mahony, S. 2008. The role of participation architecture in growing sponsored open source communities. *Industry and Innovation.* 15(2), pp. 145–168.

West, M. A. (1990). The social psychology of innovation in groups. In M. A. West & J. L. Farr (Eds.), *Innovation and creativity at work*: 309–333. Chichester: Wiley.

Wong, A., Tjosvold, D., & Liu, C. (2009). Innovation by teams in Shanghai, China: Cooperative goals for group confidence and persistence. *British Journal of Management*,20: 238-251.

Woodman, R. W., Sawyer, J. E. and Griffin, R. W. 1993. Toward a theory of organizational creativity. *Academy of Management Review*. 18, pp. 293–321.

Yu, C., Chai, Y. and Liu, Y. 2018. Literature review on collective intelligence: A crowd science perspective. *International Journal of Crowd Science*. 2(1), pp. 64–73.

Yuan, F. and Woodman, R. W. 2010. Innovative behavior in the workplace: The role of performance and image outcome expectations. *Academy of Management Journal.* 53, pp. 323–342.

Zhou, J. and Shalley, C. E. 2010. Deepening our understanding of creativity in the workplace: A review of different approaches to creativity research. In: Zedeck, S. ed. *APA handbook of industrial and organizational psychology, 1*. Washington: APA, pp. 275–302.

Zhou, J., Shin, S. J., Brass, D. J., Choi, J., & Zhang, Z. (2009). Social networks, personal values, and creativity: Evidence for curvilinear and interaction effects. *Journal of Applied Psychology,* 94: 1544-1552.

Zhou, J., & Su, Y. (2010). A missing piece of the puzzle: The organizational context in cultural patterns of creativity. *Management and Organization Review,* 6: 413.

Appendix 1: Networks with both ideas and participants

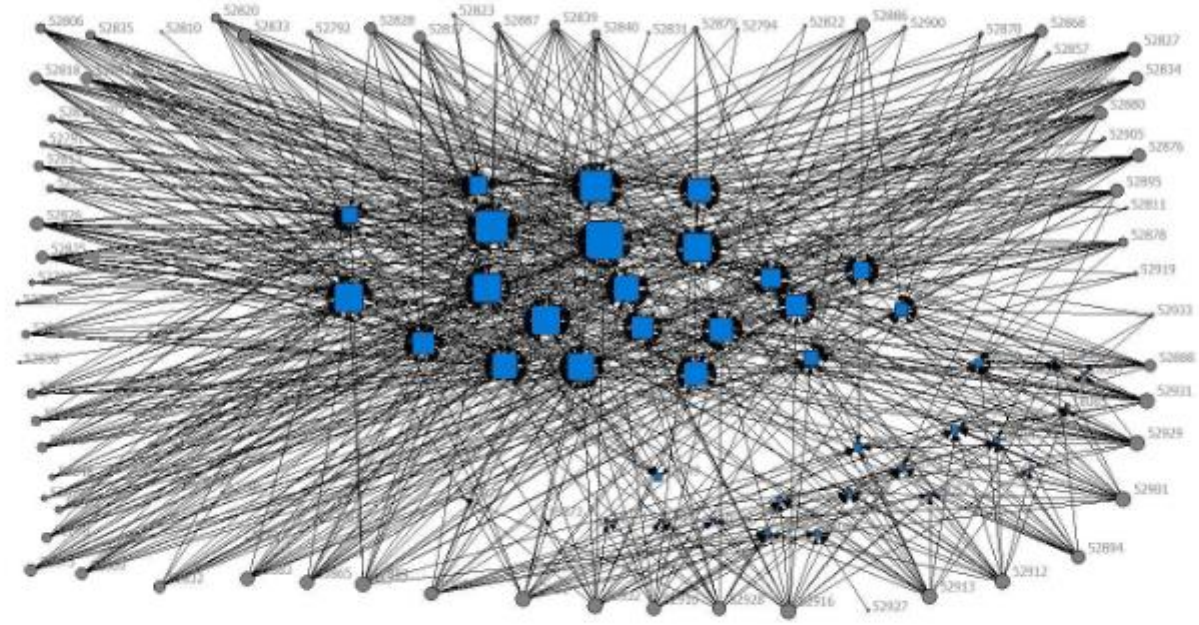
Network snapshots

Figure A1 and A2 present the network snapshots in terms of the votes from all participants in each project. The nodes are participants and ideas. To distinguish the participants and ideas, the grey circle nodes present participants. And the blue square nodes represent ideas. The lines are votes. The participants are located in the periphery in the snapshots. And ideas are located in the center. The size of idea node represents the winning ration in vote. The bigger size is the more votes won for that idea. Similarly, the size of participant node represents the number of votes voted by the participant. The ideas received large numbers of votes are located in the center. And the ideas received little votes are located at the right bottom corner.

Figure A1 Project 1 overall vote activities

Ideation topic: "What should our global New Year resolutions be?"

83 participants	42 ideas generated	1052 votes

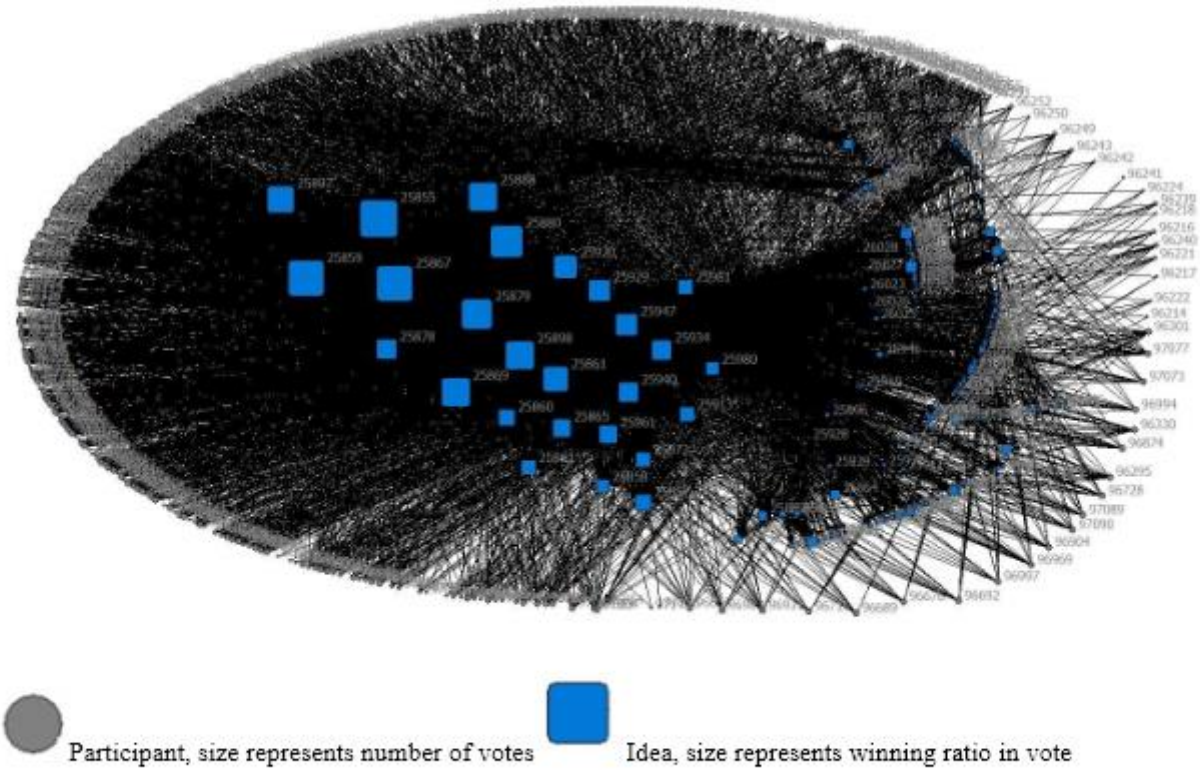


Participant, size represents number of votes Idea, size represents winning ratio in vote

Figure A2 Project 2 overall vote activities

Ideation topic: "What measures would you recommend to ensure the safety of young people on social media?"

325 participants	174 ideas generated	5220votes



Participant, size represents number of votes Idea, size represents winning ratio in vote

Figure A3 and A4 present the network snapshots about editing activities in each project. Similar to the previous snapshots, the nodes are participants and ideas. To distinguish the participants and ideas, the grey circle nodes present participants. And the blue square nodes represent ideas. Different to the previous snapshots, the lines are edits rather than votes. The size of idea node represents the winning ratio in vote. The size of participant node represents the number of edits by the participant.

Figure A3 Project 1 overall editing activities

Ideation topic: "What should our global New Year resolutions be?"

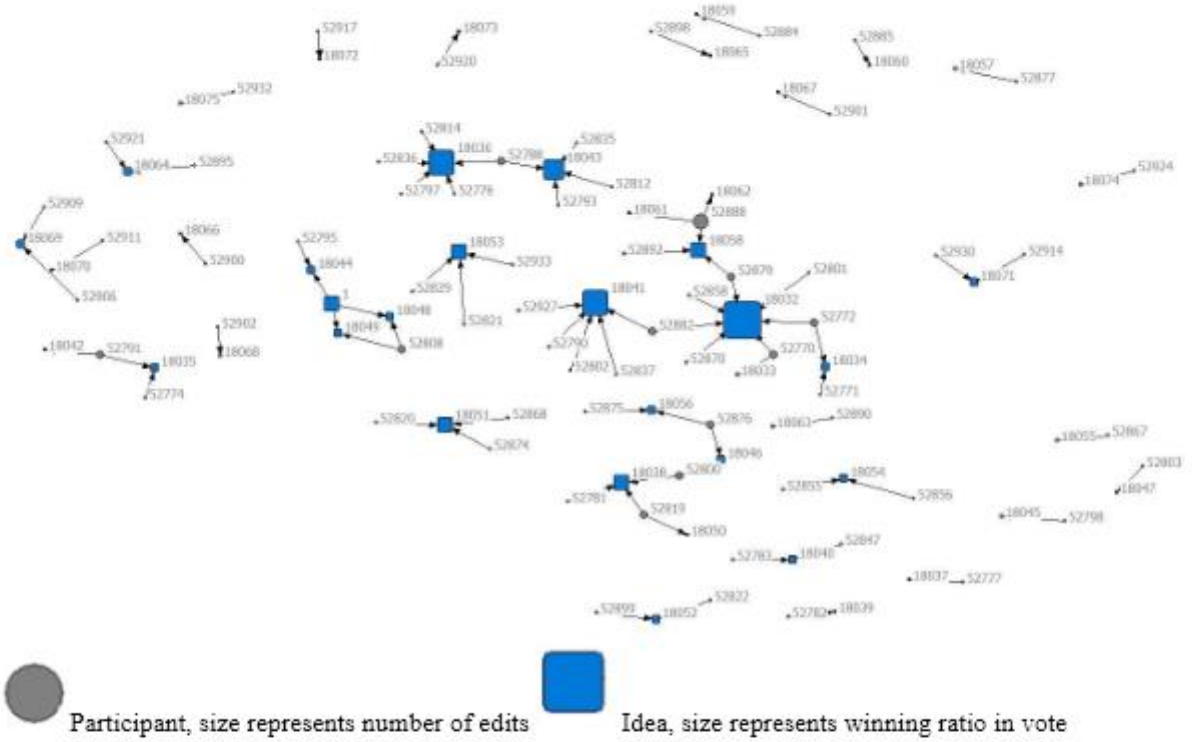
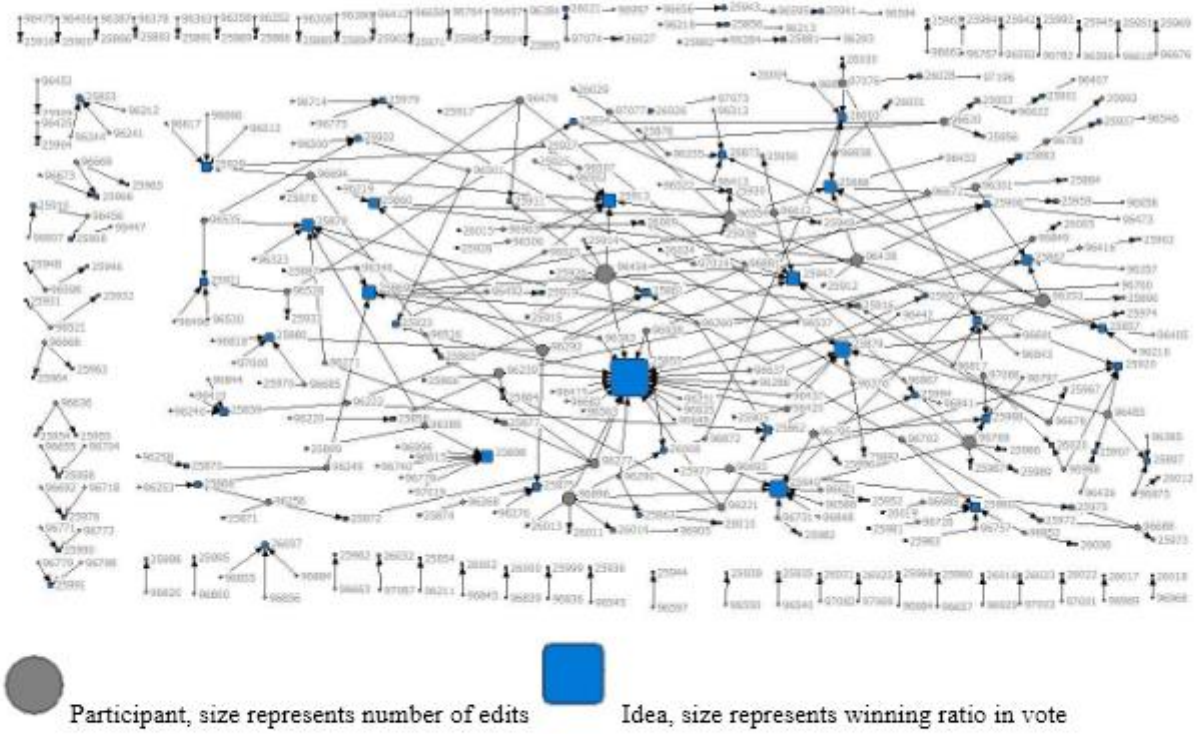


Figure A4 Project 2 overall editing activities

Ideation topic: "What measures would you recommend to ensure the safety of young people on social media?"



Participant, size represents number of edits

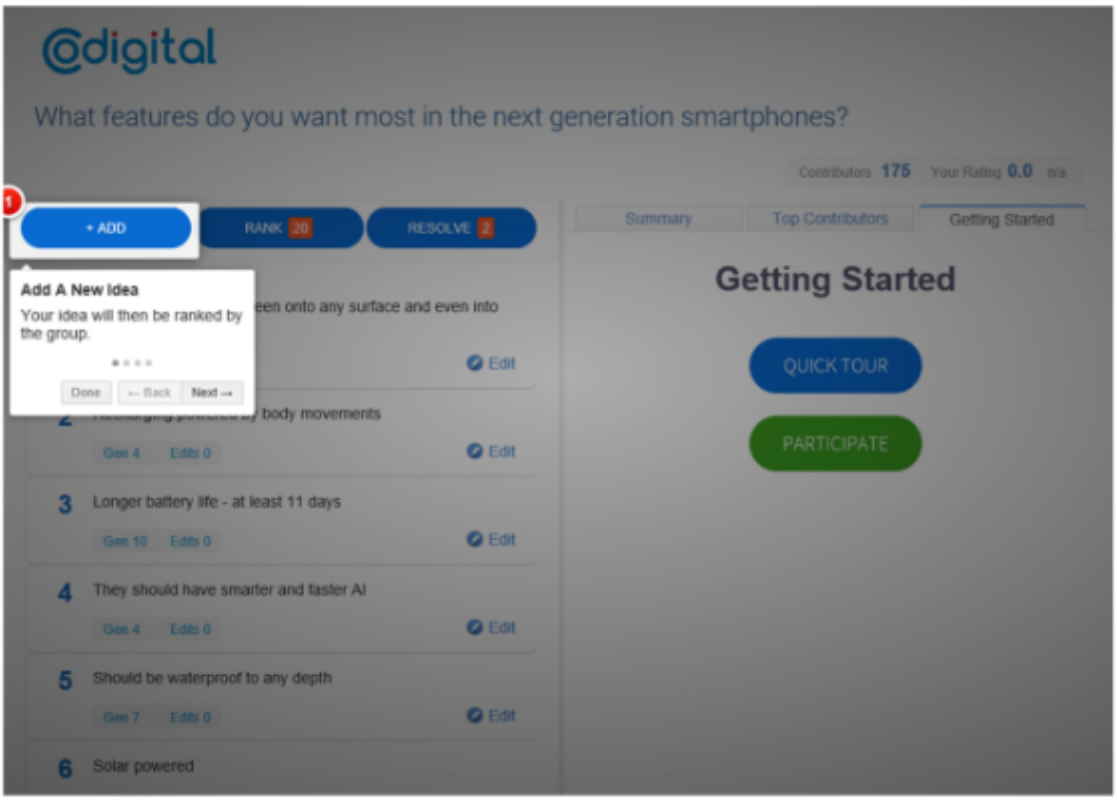
Idea, size represents winning ratio in vote

Appendix 2: Co-digital ideation platform

The Co-digital ideation tool consists of four parts, 'idea creation', 'idea edit', 'idea vote', and 'rank ideas'. These four parts are consistent with previous theories considering ideation as consisting of creation, modification, voting, and selection (Lindic, et al., 2011;Majchrzak and Malhotra, 2013; Nakatsu et al., 2014). The Co-digital ideation tool is consistent with these studies suggested. Idea creation is represented by 'add ideas' in the Co-digital ideation tool. Modification, equivalently, idea edit consists of 'edit ideas' and 'vote edits' in the Co-digital ideation tool. Idea voting is 'vote ideas' and idea selection is through 'rank ideas' in the Co-digital ideation tool. Thus, the Co-digital ideation tool adheres to the description of an effective idea generation online platform based on existing literature.

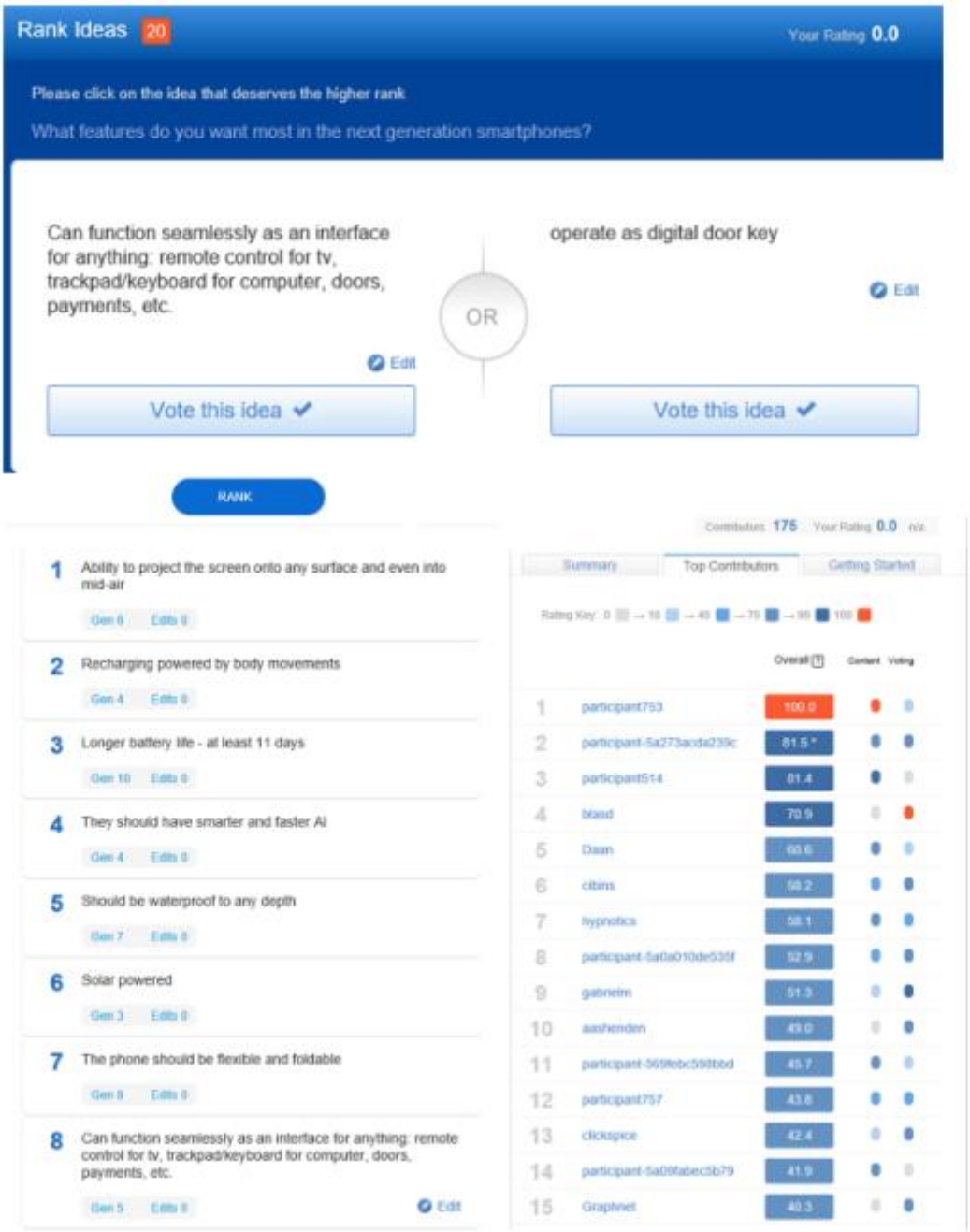
At first, 'ideas generated by participants' means ideas created and added by individual participants for a specific idea generation topic on Codigital platform (see an example in Figure A5). These ideas can be presented by using texts and pictures. Further, 'the number of ideas generated by participants' means how many ideas created and added to the platform by individual participants.

Figure A5 Examples of ideas created by participants



'Votes on the generated ideas' means votes by individual participants to decide which idea is the best (see Figure A6). In voting, deals compete for survival in pairs. The ideas with more 'likes' will stay in the next round. This is repeated until each project finish time and the ideas are ranked by number of votes received. Further, 'the number of votes on the generated ideas' means how many votes on all the generated ideas by individual participants.

Figure A6 Examples of votes on the generated ideas



'Edits on the generated ideas' means edits on participants' own ideas and edits on each other's ideas (see an example in Figure A7). Participants can improve their ideas with modifications. Also, ideas can be modified and improved through the collaborations between

participants. Further, 'the number of edits on the generated ideas' means how many edits on all the generated ideas by individual participants.

Figure A7 An example of edits on the generated ideas

Finalised ideas are voted to decide which one is the best. Each idea competes with the others through voting. Idea vote encourages competition in refining ideas. Then ideas compete for survival in pairs. The ideas with more 'likes' will stay in the next round. This is repeated and statistical analysis of all these idea pair competitions identifies the best ideas.

Codigital is be used as the platform for the co-ideation and formulation. The participants will produce ideas to 'solve' or address problems by using the Codigital platform. The ideas will be open to editing by others across the participants, and ideas will be ranked for quality of

idea (is it a good idea) and implementability (can it be implemented). While the best ideas will be implemented, the focus of this study is ideation rather than the actual implementation (see Figure A8).

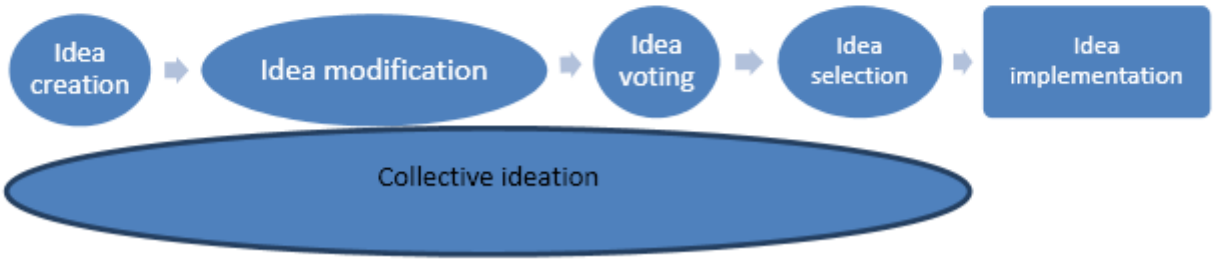


Figure A8 Collective ideation and idea implementation

In sum, the Co-digital ideation tool consists of four parts, 'idea creation', 'idea edit', ' idea vote', and 'rank ideas'. These four parts are consistent with previous theories considering ideation as consisting of creation, modification, voting, and selection (Lindic, et al., 2011; Majchrzak and Malhotra, 2013; Nakatsu et al., 2014).

Appendix 3: Network analysis

Stage 1 Generating networks

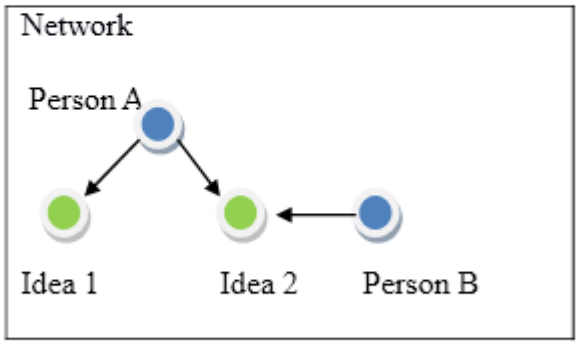
In order to generate vote, edit, and creator networks, three tables need to be extracted from the data. They are: 1) a vote table with a column of voter and a column of ideas each voter voted, then each row is 'who voted to which idea'. 2) A edit table with a column of editor and a column of ideas each editor edited, then each row is 'who edited which idea'. 3) A creator table with a column of idea creator and a column of ideas each creator created, then each row is 'who created which idea'. These three tables can be done by copy paste from the data.

Each table generated in the previous step can be loaded into Ucinet software to be transformed into a 0/1 matrix. For example, Person A voted to both Idea a and b, Person B voted to idea b only (see Figure A9). In network data, this network is coded as a matrix with Person A, and B, and Idea a and b as both column and row. If there is a connection between two of them, there is 1 at the intersection. If not, there is 0 at intersections. Then, networks can be drawn based and calculated based on the numbers in the matrix. These networks of participants and ideas are attached in Appendix 1. Then, they can be transformed into networks consists of ideas as nodes and votes, edits and creations by the same participants as ties. This can be done by using 2 mode network function in Ucinet.

Figure A9 Network data

	Person A	Idea a	Idea b	Person B
Person A	0	1	1	0
Idea a	1	0	0	0
Idea b	1	0	0	1
Person B	0	0	1	0

Network generated by the data above

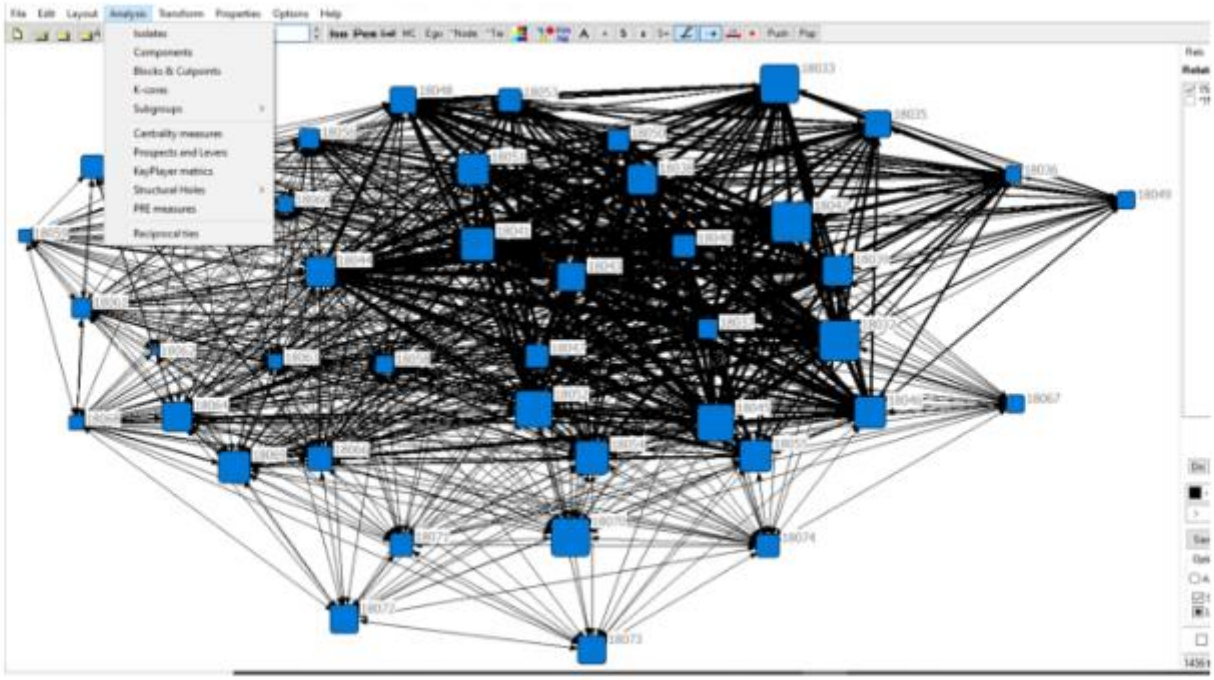


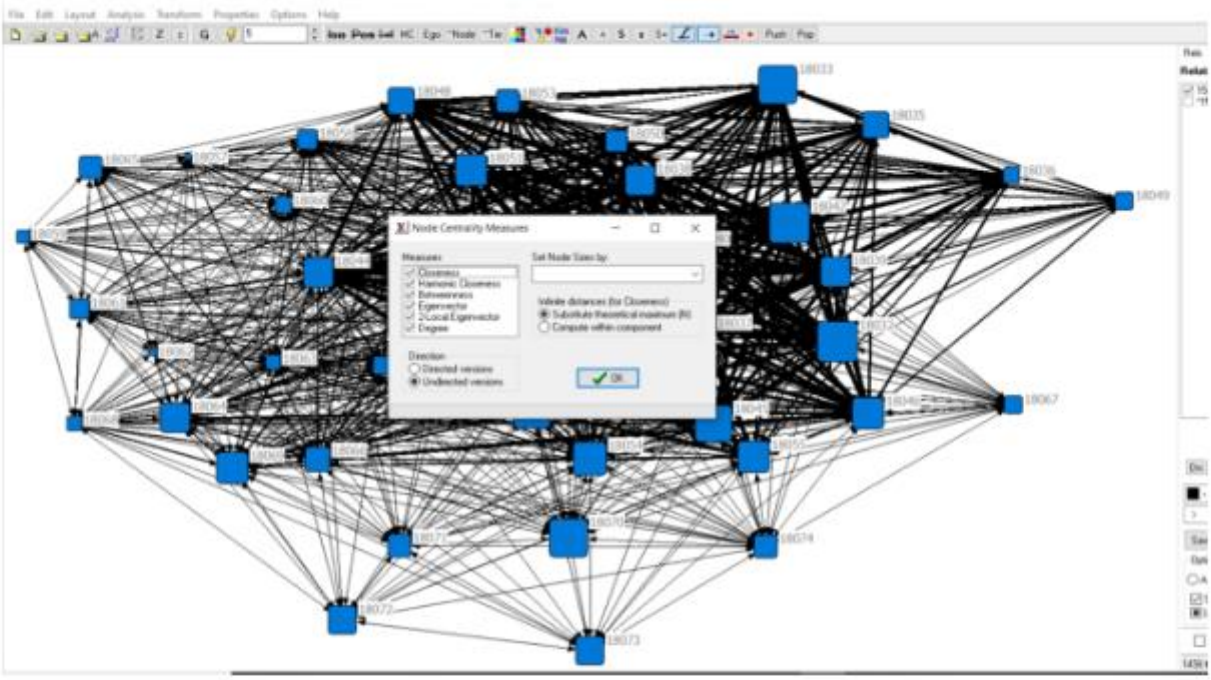
Stage 2 Calculating variables

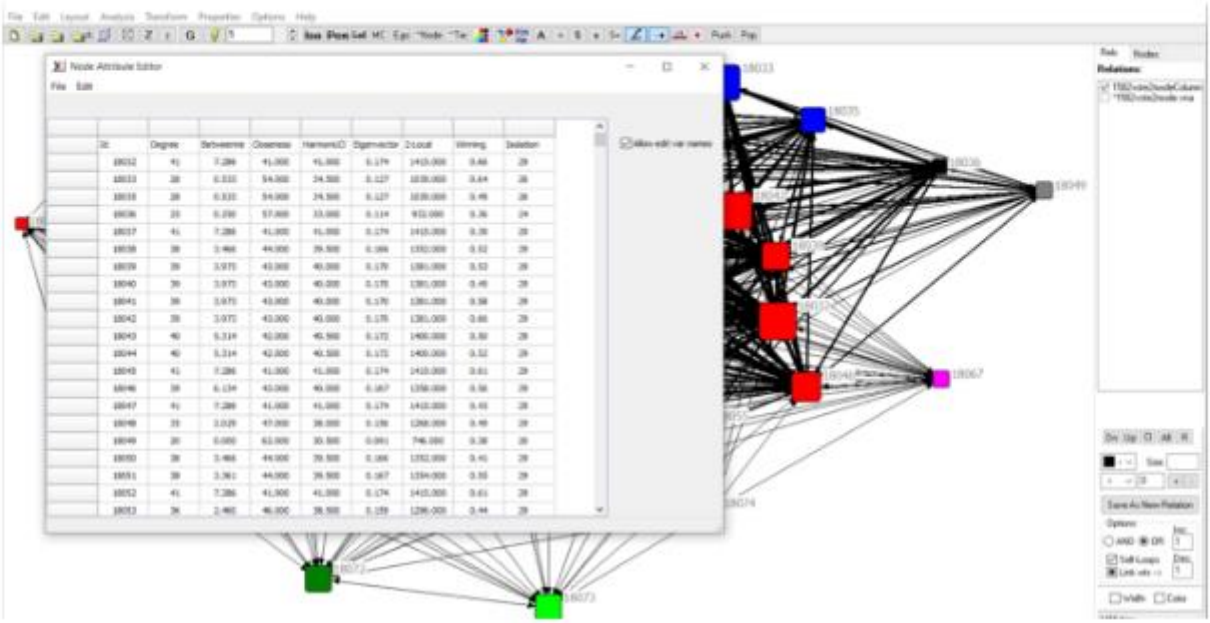
After the networks are generated, centralities can be calculated. Betweenness, closeness and eigenvector centrality can be calculated by using the centrality function in Ucinet (see Figure A10). The isolation and inactivity can be calculated by using the isolation and inactivity function in Ucinet. The number of votes, edits each idea received can be calculated by using connection count function in Ucinet. Similarly, the number of ideas created by each participant can be calculated as well. The number of votes, edits each idea received can be

calculated by using connection count function in Ucinet. Similarly, the number of ideas created by each participant can be calculated as well. Size of each project (the number of participants) can be calculated by using nodes count function in Ucinet. The total number of votes and edits can be calculated by using connection count function in Ucinet. Then vote engagement and edit engagement can be calculated by the total number of votes/ the number of participants and the total number of edits/the number of participants.

Figure A10 Generating centralities, isolation and inactivity using Ucinet







Idea appearances in vote can be counted by using excel. Similarly, times of wins and losses can be counted by using excel, then calculate winning ratio of each idea (times of wins/losses). Then, the table containing idea appearances and winning ratio (generated in the last step) can be merged with the rest of the data. This can be done by using vlook function in Excel. And it is necessary to check whether the sample size is consistent in these two tables and avoid missing data. To avoid the size differences between two ideation projects, the data needs to be normalised. To do this, this study deducts the minimum value of the variable, and

then divided by the difference between the maximum value and the minimum value (Cronk, 2019).